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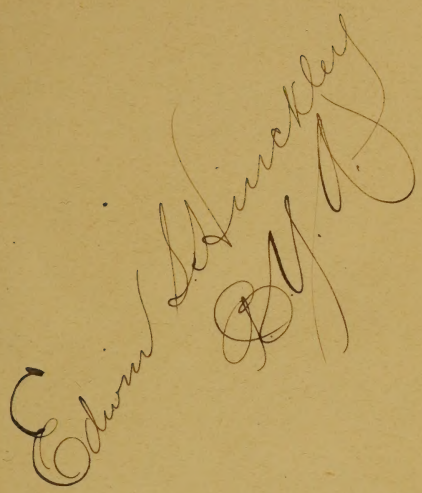

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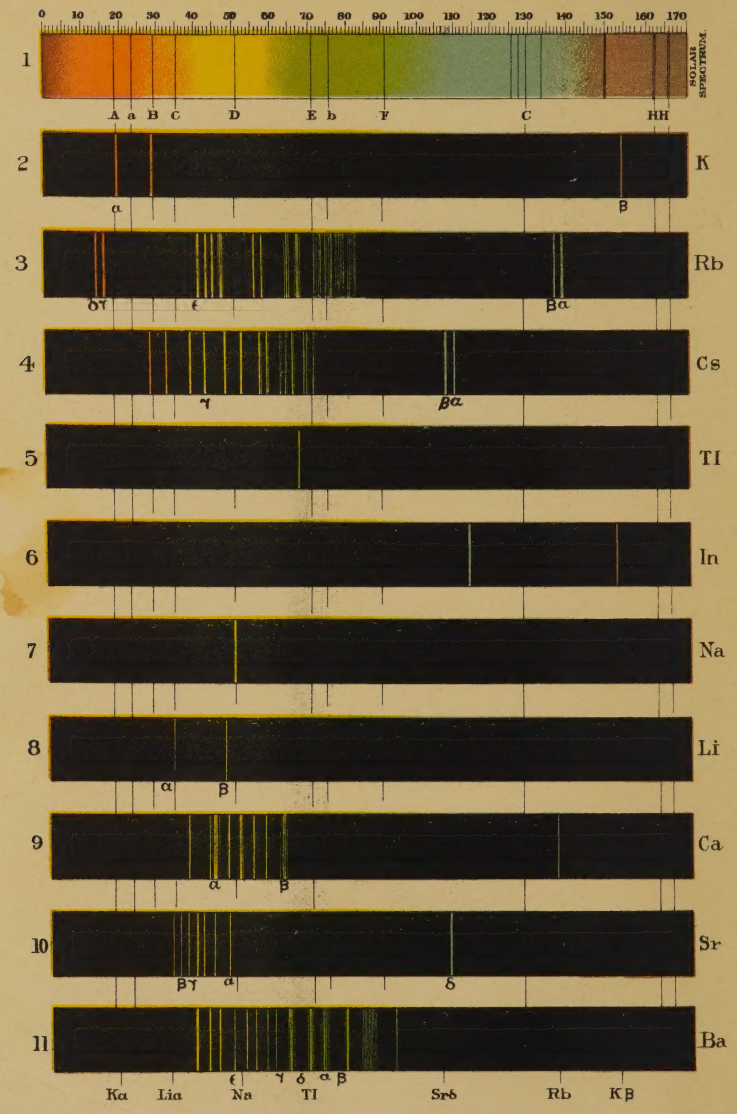

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ELDERHORST'S MANUAL

REWRITTEN AND REVISED.

MANUAL

OF

QUALITATIVE

BLOWPIPE ANALYSIS,

AND

DETERMINATIVE MINERALOGY.

169255

BY

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PREFACE.

A MANUAL of blowpipe analysis was prepared by Prof. Elderhorst nearly twenty-five years ago for use in the Rensselaer Polytechnic Institute, there being at that time no text-book which seemed well adapted to the course of instruction as it was here given. To the second edition a translation of a portion of von Kobell's *Tables* (fifth edition) was added.

A complete revision, with many alterations and additions, was afterward made by the editor of this volume, with the assistance of Prof. C. F. Chandler, which has continued in use to date, having passed through several editions. As the demand for the book has continued, it has been thought advisable to bring it up to the present time, which has involved a total change and nearly an entire rewriting.

A new arrangement of subjects, a change of nomenclature and chemical formulas, have been made, and many new methods of determination of compounds and minerals have been introduced. Still, the present work may be considered as based upon, or having grown out of, the later editions of Elderhorst's *Manual.*

In the present compilation the following works have been consulted:

The editions of Elderhorst's *Manual* revised by Nason and Chandler; the German translation of the same by Landauer; von Kobell's *Tafeln zur Bestimmung der Mineralien* (11th edition); Rammelsberg's *Mineral-Chemie;* Plattner's *Blowpipe Analysis*, translated by Cornwall; Dana's (J. D.) *Descriptive Mineralogy;* Dana's (E. S.) *Text-Book of Mineralogy;* Ross's *Pyrology;* and various articles in scientific journals.

My thanks are due for many valuable suggestions to Dr. C. F. Chandler of Columbia College, Dr. H. C. Bolton of Trinity College, Prof. A. R. Leeds of the Stevens Institute of Technology, and especially to Dr. J. Landauer of Braunschweig, whose *Tables* have been introduced in this work.

My thanks are also due to Mr. W. P. Mason, C. E., my assistant, for much valuable aid in the preparation of this volume.

WINSLOW LABORATORY,
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Troy, N. Y., Dec. 15, 1880.

INTRODUCTION.

At present a knowledge of blowpipe operations is considered not only convenient, but quite indispensable, to the chemist, mineralogist, geologist, and mining engineer. The small amount of apparatus and few reagents necessary, the ease, quickness, and certainty with which the results are obtained, often render blowpipe methods preferable to all others.

A list of the more important apparatus and reagents is given in Chap. I.

The structure of the flame, and the manner of producing the oxidizing and reducing flames, are explained at the beginning of Chap. II.

In accordance with the instructions there given, with a little practice these flames may be readily produced, and also a steady and continuous blast.

A series of experiments may then be made with suitable substances "In the closed tube," "In the open tube," etc.

The following substances will be found well adapted for exhibiting the effects which may be produced:

1. For examination in the glass tube closed at one end: lime, ammonium nitrate, zinc oxide, mercury oxide, copper sulphate, lead carbonate, manganese dioxide, stibnite, pyrite, cinnabar, siderite, fluorite (see pars. 8–12).

2. In the open tube: bismuth, selenium, arsenopyrite, pyrite, stibnite, cinnabar, galenite, sphalerite, molybdenite (see pars. 13–20).

3. On charcoal or aluminium foil: arsenopyrite, selenium, pyrite, antimony, bismuth, zinc, lead, potassium chlorate, sodium carbonate (see pars. 21–38).

4. In the borax or salt of phosphorus bead: cobalt, nitrate, iron oxide, manganese dioxide, chromium oxide, copper oxide, silica (see pars. 39–41).

5. With sodium carbonate: metallic oxides, silica, sulphur, barium, and strontium (see pars. 42–46).

6. With sodium thiosulphate: metallic oxides (see par. 47).

7. With acid potassium sulphate: nitrates, chlorates, iodides, bromides, acetates, etc. (see pars. 48–50).

8. With zinc and hydrochloric acid after previous decomposition: molybdenum oxide, etc. (see par. 51).

9. With cobalt solution: alumina, magnesia, zinc oxide, etc. (see pars. 52–55).

10. For flame coloration: sodium, potassium, barium, strontium, etc. (see pars. 56–61).

The following substances may then be examined, with and without fluxes, as indicated in the tables on pages 189–215:

1. Iron sesquioxide, all the reactions given in Table II. 13.
2. Manganese dioxide, Table II. 16.
3. Chromium sesquioxide, Table II. 6.
4. Cobalt and nickel oxides, Table II. 7, 19.
5. Copper oxide, Table II. 8.
6. Zinc oxide, Table II. 35, and metallic zinc (pars. 34–55).
7. Tin oxide, Table II. 30, and metallic tin (par. 28).
8. Lead oxide, Table II. 15, and metallic lead (par. 27).
9. Bismuth oxide, Table II. 3, and metallic bismuth (pars. 17–26).
10. Antimony trioxide, Table II. 1, and metallic antimony (pars. 16–25).
11. Arsenic trioxide, Table II. 2 (pars. 15–33).
12. Mercury oxide, Table II. 17.
13. Alumina, Table I. 5, and par. 55.
14. Magnesia, Table I. 4, and par. 55.
15. Silica (par. 55).
16. A sulphide (pars. 10, 14, 121).
17. A borate (par. 75).
18. A chloride (pars. 82, 83).

Having made these examinations carefully, and having performed all the operations indicated, the analyses of simple substances may be undertaken, and afterward of the more complex and difficult.

Methods of experimenting may be learned from the examples given, or, if considered preferable, the analyses may be made by use of the systematic tables given on pages 169–

188. Such tables may be of some assistance to the beginner, but after little experience it will be better to lay them aside and depend upon the judgment in regards to the tests to be made and the inferences to be drawn therefrom. This method may be illustrated and easily understood from the following examples given by Elderhorst:

1. The substance under examination is antimony sulphide.

Examination in a matrass: At a very high temperature a black sublimate is obtained, becoming reddish-brown when cold. In reading over the list (in par. 10) we find this character belonging to antimony sulphide.

Examination in an open glass tube: Gives sulphur dioxide, detected by the odor and action on blue litmus-paper, and white fumes, which partly condense in the tube. On examining the sublimate with a magnifying-glass, it is found to be amorphous, hence must be antimony trioxide (par. 16).

Examination on charcoal alone: Is completely volatilized, with emission of sulphur dioxide, and deposits a white volatile coating, possessing the properties of the coating of antimony (par. 25).

These few operations are quite sufficient to establish the nature of the substance under trial, since the absence of the more fixed metals proved by the volatility of the substance on charcoal and in the open tube, and the absence of metals giving coatings by the purity of the antimony coating. The presence of arsenic would have been betrayed by an alliaceous odor when heated on charcoal. The only substance which would have escaped detection by these operations is mercury sulphide. In order to ascertain its presence or absence, we perform the operation given under "*Mercury*" in Chap. III.

The result giving an answer in the negative, the body was "antimony sulphide."

2. The substance under examination is lead chromate.

Examination in a matrass: } Fuses and changes color, but
Examination in an open tube: } gives nothing volatile.

Examination on charcoal alone: Fuses, gives small metallic globules, and deposits a coating which is lemon-yellow while hot, and sulphur-yellow when cold, indicative of lead (par.

23). It is always desirable to collect the metal to a large globule, and to study its physical properties. This end is best attained by mixing the substance with sodium carbonate and a little borax, and exposing the mixture to the reduction flame on charcoal. In this particular case a metallic button is obtained which is soft, may be flattened by the hammer and cut by the knife—properties belonging to metallic lead.

Examination with borax and salt of phosphorus: Before proceeding with this examination it is necessary to test the substance for the presence of sulphur after the method given in par. 121 (unless the presence of this element was detected by the examination in the open glass tube or on charcoal alone); no sulphur being present, borax and salt of phosphorus beads are made on charcoal, and small portions of the substance added. With both fluxes nearly the same reactions are obtained; in oxidation flame dark-red while hot, and fine yellowish-green when cold; in reduction flame green, hot and cold. In order to find out what body produces such reactions, we use Table II., which leads us to chromium sesquioxide. To corroborate the result, the substance may be fused with sodium carbonate and nitre, as described (par. 85).

The physical properties of the body under trial lead to the final conclusion that it must be lead chromate.

3. The substance is an alloy of silver, copper, and lead.

Examination in a closed tube: } no change.
Examination in an open tube: }

Examination on charcoal alone: Fuses and deposits a copious coating, which is lemon-yellow while hot and sulphur-yellow when cold, indicative of lead (par. 27); the coating cannot contain any bismuth oxide, because the color would be darker in this case, but might contain zinc oxide or antimony oxide. The test is for the presence of the former, the coating is played upon with the oxidation flame: it is completely volatile, hence no zinc present (might also be tested with cobalt solution, par. 54); to test the coating for the presence of antimony oxide, it is scraped off from the charcoal and dissolved in a bead of salt of phosphorus (v. page 56), or the alloy is treated with boric acid, as described under the head of "*Antimony*" in Chap. III. If the blast be continued for a long time, a faint

dark-red coating is formed near the assay-piece, indicative of silver (par. 29), and a dark metallic globule remains.

Examination with borax and salt of phosphorus: the globule remaining on the charcoal after volatilization of the lead is treated with borax on charcoal in oxidation flame; the borax becomes colored. Owing to the reducing effect of the charcoal, the influence of the oxidation flame cannot be well observed on charcoal; hence the borax is removed from the metallic globule, fastened into the hook of a platina wire, and here exposed to the action of the oxidation flame; the bead is green while hot, and blue when cold. On consulting Table II. we find that this reaction is produced by copper oxide, and by a mixture of cobalt oxide and iron sesquioxide; to decide between the two, we now expose the bead to the action of the reduction flame; it becomes red and opaque, thus proving the presence of oxide of copper.

By examination on charcoal alone, we were led to suspect the presence of silver; in order to establish this beyond a doubt, we refer to Chap. III., "Silver;" here we find a method (par. 119) by which the presence of silver may be ascertained in compounds of all descriptions. In our case, having to deal only with lead, copper, and silver, the treatment with vitrified boric acid and metallic lead is, of course, superfluous. We place our alloy at once on the cupel, and direct the oxidation flame upon it; if, after cessation of the rotatory motion, the globule should not possess the bright lustre of silver, some pure metallic lead has to be added in order to remove the last traces of copper. We finally obtained a bright globule exhibiting all the characteristic properties of silver.

Thus we have established the presence of lead, copper, and silver.

4. The substance under examination is copper nickel, containing arsenic, sulphur, nickel, cobalt, and iron.

Examination in a matrass: Gives a slight sublimate, consisting of octahedral crystals, pointing to the presence of arsenic (par. 11).

Examination in a glass tube open at both ends: Gives a copious crystalline sublimate of arsenic trioxide, and a faint odor of sulphur dioxide; to establish the presence of sulphur beyond doubt, we refer to Chap. III., "Sulphur," where we find

the method (par. 121) for discovering sulphur when in combination with other substances. In performing the test there described we obtain the sulphur reaction.

Examination on charcoal alone: Gives abundant arsenic fumes, leaving a metallic globule which, even with continued blowing, does not give rise to the formation of a coating on the charcoal (absence of volatile metals).

Having removed all volatile substances, we now proceed to examine the remaining globule. On applying a magnet, we find it powerfully attracted, showing the presence of either iron, nickel, or cobalt, perhaps all of them, either alone or combined with other non-volatile metals. We add some borax to the globule and expose it to the action of the oxidation flame, then remove the borax from the globule, fasten it into the hook of a platinum wire, and here observe the color: green while hot, blue when cold as in the preceding case (example 3), but on exposing the bead to the action of the reduction flame (which is best done by placing it on charcoal and touching it with tin), it does not become brown and opaque, showing therefore the presence of a small quantity of iron with cobalt. We now add a fresh portion of borax to the metallic globule, in order to see whether it consists entirely of cobalt (that it cannot contain any considerable amount of iron is proved by the appearance of the cobalt reaction in the first trial, iron being much more readily dissolved by borax than cobalt): the bead is violet while hot, and assumes a brownish color on cooling; by referring to Table II. we see that this effect is produced by nickel containing cobalt. Referring to Chap. III., "Nickel," we find the method to detect the presence of this metal when in combination with iron and cobalt, and also the presence of copper, if the assay should contain a small quantity of it.

By the above examples the use of the methods given in the third chapter will be sufficiently illustrated. If the substance under examination be of a simple composition, its nature is readily ascertained by following the general method laid down in the second chapter; but if the reactions obtained clearly point to the complex nature of the body, we refer to the respective sections of Chap. III.; if, for example, we suspect the presence of cobalt in a mineral consisting of arsenides, we test the substance according to par. 86; if a small quantity of

copper is to be discovered in a mineral, we proceed as directed in par. 88, etc.

In order to obtain characteristic reactions and satisfactory results it is important to experiment upon a suitable substance. A list of such substances which are sufficient to illustrate all the important reactions may be found on page 16. In Chapters II. and III., when a reaction is mentioned or a process described, a number is often added which refers to the substance in the list well adapted for the experiment, p. 12.

In Part II., Chap. VI., all necessary instructions for the determination of mineral species are given. The names of the most important minerals, or of most frequent occurrence, are printed in large type; of the less common, in somewhat smaller type; and the comparatively rare or wholly foreign, in *italics*.

A set of minerals, in small fragments, placed in corked glass tubes, numbered and arranged in a small box provided with partitioned trays, will be found very convenient for study and for reference. The box and trays may be made of heavy pasteboard, and the following dimensions will answer well the purpose: seventeen centimeters in length, thirteen centimeters in breadth, and four centimeters in depth. The glass tubes are five and a half centimeters in length and one centimeter in diameter. The trays, three in number, will hold seventy-two specimen tubes, in which the minerals of the list on the following page may be placed. These having been carefully studied, but little difficulty will be found in determining any of the minerals described in the tables in Chapter VI.

MINERALS FOR BLOWPIPE ANALYSIS.

Potassium.
Orthoclase.
Apophyllite.

Sodium.
Albite.
Natrolite.
Cryolite.

Lithium.
Lepidolite.
Spodumene.

Barium.
Barite.
Witherite.

Strontium.
Celestite.
Strontianite.

Calcium.
Fluorite.
Gypsum.
Apatite.
Calcite.
Wollastonite.
Prehnite.

Magnesium.
Magnesite.
Talc.
Dolomite.
Serpentine.

Aluminium.
Corundum.
Cyanite.
Topaz.

Glucinum.
Beryl.

Manganese.
Pyrolusite.
Franklinite.
Rhodonite.

Iron.
Hematite.
Limonite.
Magnetite.
Siderite.
Pyrite.

Cobalt.
Cobaltite.

Nickel.
Niccolite.

Zinc.
Zincite.
Sphalerite.
Calamine.
Willemite.

Lead.
Galenite.
Cerussite.
Pyromorphite.
Bournonite.

Tin.
Cassiterite.
Stannite.

Bismuth.
Native bismuth.

Copper.
Cuprite.
Chalcocite.
Bornite.
Chalcopyrite.
Tetrahedrite.
Malachite.
Azurite.

Mercury.
Cinnabar.

Silver.
Argentite.
Cerargyrite.
Pyrargyrite.

Titanium.
Menaccanite.
Rutile.

Antimony.
Stibnite.

Tungsten.
Wolframite.

Molybdenum.
Molybdenite.

Chromium.
Chromite.

Arsenic.
Realgar.
Orpiment.
Arsenopyrite.

Boron.
Sassolite.
Tourmaline.

Silicon.
Quartz.

Carbon.
Succinite.
Graphite.

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ABBREVIATIONS.—R. F. Reducing flame.—O. F. Oxidizing flame.—G. Specific gravity.—H. Hardness.—Aq. Water.—A barred letter signifies two of the element.

LIST OF SUBSTANCES

Well Adapted for Showing the most Important Blowpipe Reactions.

Metals.

1. Antimony.
2. Arsenic.
3. Lead.
4. Bismuth.
5. Cadmium.
6. Zinc.
7. Tin.
8. Silver.

Alloys.

9. Mercury and tin.
10. Lead and antimony.
11. Lead and bismuth.
12. Lead and zinc.
13. Lead, copper, and silver.
14. Copper and zinc.
15. Copper and tin.
16. Zinc and cadmium.

Sulphides.

17. Arsenic and antimony (artificial).
18. Arsenic, antimony, lead, and copper (artificial).

Oxides.

19. Antimony oxide.
20. Bismuth oxide.
21. Cadmium oxide.
22. Zinc oxide.
23. Tin oxide.
24. Iron oxide.
25. Chromium oxide.
26. Copper oxide.
27. Cobalt monoxide.
28. Uranium oxide.
29. Tungsten trioxide.
30. Molybdenum trioxide.
31. Arsenic trioxide.
32. Alumina.

Salts.

33. Borax.
34. Salt of phosphorus.
35. Sodium carbonate.
36. Acid potassium sulphate.
37. Ammonium chloride.
38. Potassium chloride.
39. Potassium bromide.
40. Potassium iodide.
41. Sodium chloride.
42. Potassium chlorate.
43. Lead nitrate.
44. Cobalt nitrate.
45. Nickel oxalate.
46. Copper sulphate.
47. Copper chloride.
48. Copper arsenate.
49. Mercurous chloride.
50. Mercuric chloride.

Minerals.

51. Quartz.
52. Gypsum.
53. Calcite.
54. Strontianite.
55. Witherite.
56. Magnesite.
57. Muscovite.
58. Orthoclase.
59. Albite.
60. Petalite.
61. Hematite.
62. Rutile.
63. Pyrolusite.
64. Lepidolite.
65. Apatite.
66. Franklinite.
67. Uraninite.
68. Chromite.
69. Cerussite.
70. Malachite.
71. Stibnite.
72. Pyrite.
73. Chalcopyrite.
74. Arsenopyrite.
75. Smaltite.
76. Cobaltite.
77. Realgar.
78. Cinnabar.
79. Niccolite.
80. Molybdenite.
81. Berthierite.
82. Bournonite.
83. Tetrahedrite.
84. Tiemannite.
85. Sylvanite.
86. Descloizite.

PART I.

BLOWPIPE ANALYSIS.

CHAPTER I.

APPARATUS AND REAGENTS.

1. The blowpipe in general use at the present time is shown in Fig. 1. It consists of a conical tube, *a b*, provided with a mouth-piece, *a*; a cylindrical chamber, *c d*, to retain the condensed moisture of the breath; and a short tube, *f g*, inserted at right angles to this chamber. This latter tube is terminated with a platinum jet, *h*, which may be adjusted to hold by friction or may be soldered to the tube. The terminal opening of the jet should be 0.4 mm. in diameter. When a stronger flame is required, a diameter of 0.5 mm. will be found useful. Should the opening become obstructed, it may be cleared by removing the jet from the tube and heating to moderate redness. The trumpet-shaped mouth-piece is generally preferred, although other forms may be used. The usual length of the blowpipe, without the mouth-piece, is 200 mm., but this

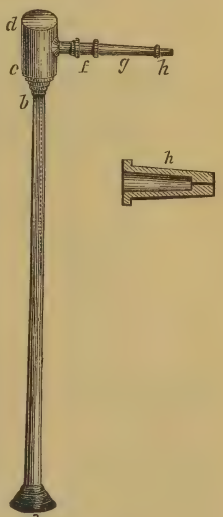


Fig. 1.

length may be varied to suit the visual distance of the operator.

Other forms of blowpipe for special work are frequently employed; as, for instance, the stand blowpipe, which permits both hands being at liberty. This latter, in some cases, has a mechanical blowing-attachment operated by the hand or foot. In most laboratories hydraulic pressure may be conveniently used for producing a steady and long-continued blast. The gas blowpipe, Figs. 2 and 3, supplying the fuel and blast through the

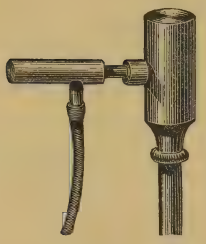


Fig. 2.

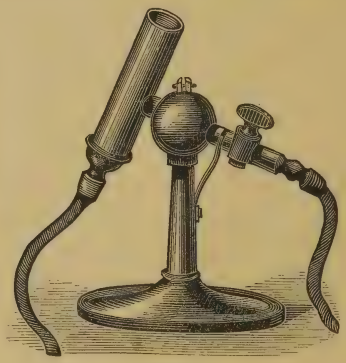


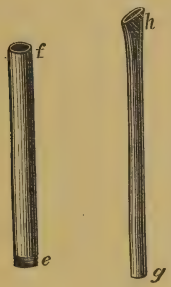
Fig. 3.

same jet, and used with or without a mechanical blower, is particularly worthy of notice.

In Fletcher's blowpipe the end of the tube is bent round several times, and this becomes heated by the flame when in use. A hot-air blast is thus produced, and the temperature of the blowpipe flame is considerably increased.

2. Any kind of a flame may be used for the blowpipe, provided it be not too small. The flame of illuminating gas, however, is most convenient for blowpipe experi-

ments, except when testing for sulphur, and the Bunsen burner best suited for the purpose. Fig. 4. The burner rests on a foot, *a b*, into which a block, *c d*, is screwed. To this is attached the tube, *e f*, in which the gas, coming through *k*, mixes with the air drawn through the



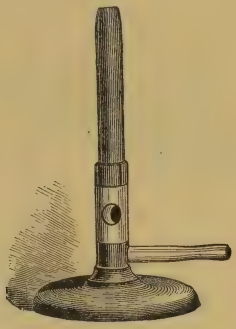


Fig. 5.

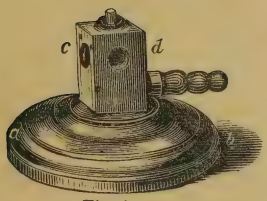


Fig. 4.

Fig. 6.

holes in *c d*, and burns at *f* with an almost non-luminous flame.

For blowpipe purposes, the tube *g h*, flattened at the top and slanted, is introduced into the tube *e f*, through which the gas passes without being mixed with the air, and burns with its usual luminous flame. The heating of substances in glass tubes and matrasses is best performed over the non-luminous flame, as it deposits no soot, or over a common alcohol lamp.

An improved form of burner by Morton is shown in Fig. 5, which does not allow the flame to retreat into the tube, but is extinguished under conditions which would cause retreat of the flame in other burners. A cap for the above burner by Leeds is shown in Fig. 5, which converts the flame into one fit for use with the blowpipe, and furnishes support to steady and direct the blowpipe jet.

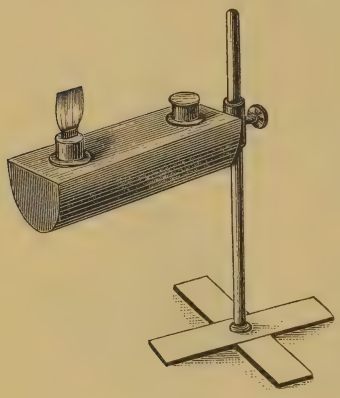


Fig. 7.

The Berzelius blowpipe lamp, Fig. 7, consists of a receptacle for oil, provided with a flat wick, and supported upon a stand. Refined rape-seed or olive oil should be used in this lamp, being cleaner and having less odor than sperm oil.

A very convenient form of lamp is described by Foster. It may be made of tin-plate, brass, or other metal. A vertical section of the whole lamp is shown in Fig. 8.

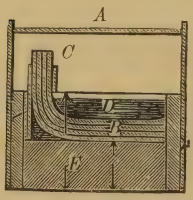


Fig. 8.

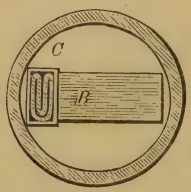


Fig. 9.

Fig. 10.

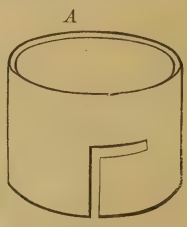


Fig. 11.

A is the cover, also shown in Fig. 11, which covers the whole lamp, and is kept in place by a knob and slot. It may also serve as a stand for the lamp when in use. E is the body of the lamp; B the flat-folded wick, shown also in Fig. 10; C the wick-holder, shown also in Fig. 9, a view of the lamp, without cover, from above; D the solid fuel, which may be tallow, stearin, paraffin, or wax, etc.

In using the lamp, the wick is lighted, and the flame then directed upon the fuel so as to melt it.

After use, and before the fuel solidifies, it is well to draw the wick up a little, that it may be ready for lighting at another time.

An alcohol lamp with a flat wick, or an ordinary low "fluid" lamp with a small cylinder, which slides up and down on the tube holding the wick, by which the flame may be adjusted, is in some respects the best substitute for the Bunsen burner and illuminating gas. In this latter form of lamp a mixture of one part of turpentine, or three parts of benzol, to twelve parts of alcohol, should be used.

The heat produced by the flame of a good stearic acid candle is quite sufficient for most blowpipe purposes. To prevent the running of the melted material, Casamajor recommends wrapping the candle closely with rather thick tin-foil. The edges should be folded together several times and then pressed against the candle, so as to form a close joint.

3. **Supports.** **Charcoal**, **platinum**, and **glass** are principally used as supports. Wood charcoal is in most cases the best, on account of its infusibility, non-conductivity, and reducing power. It must be well burnt, and

not scintillate or smoke; it must leave but little ash; charcoal of light-wood, as alder and pine, has been found the best. It should be sawn into blocks about 10 cm. long and 3 cm. in breadth and thickness. Only those sides which show the rings of growth should be used.

An excellent substitute for wood charcoal is prepared by mixing charcoal dust with starch paste, moulding into the desired form, drying, and heating to dull redness in a closed vessel or until combustible gases cease to be given off.

Aluminium foil has been highly recommended by Ross, in his treatise on "Pyrology," as a substitute for charcoal, and may be often used to advantage, especially for sublimates or coatings. On to a piece of heavy foil, about 120 mm. long, 35 mm. broad, and one end bent up so as to form a rim 20 mm. deep at a slightly acute angle to the body of the foil, a small piece of charcoal, about 12 mm. square and about the thickness of a penny, is laid, upon which the substance under examination is placed. The foil may be cleaned by rubbing with a little bone-ash and water, and is quite durable.

Platinum is used whenever the reducing action of the charcoal acts injuriously. It is advantageously employed on all occasions where no reduction to the metallic state takes place, since the color of the flux is much better seen on the platinum than on charcoal. It is mostly used in the shape of wire, the end of which is bent so as to form a hook, which serves as a support to the flux. Fig. 12. For convenience it is sealed into a drawn-out glass tube, which serves as a handle. The U-shaped hook forms a spherical bead, and is generally used, whilst the

oval-shaped hook forms a flatter bead, and is preferable when the color of the bead is very deep. A small platinum spoon or capsule, of from about 12 to 15 mm. diameter, is very convenient for fusing substances with fluxes, as nitre, acid potassium sulphate, etc. Figs. 13 and 14. A rectangular piece of **platinum foil**, about 50 mm. long and 15 mm. wide, bent up at the sides and end, may be used in place of the spoon.

Impurities are dissolved and removed from the platinum by placing in dilute sulphuric acid and rinsing with water.

Glass tubes, open at both ends, are used for calcination, and for testing the presence of substances which are volatile at a high temperature. The tubes should be about 6 mm. in diameter and 80 mm. in length. Of glass tubes, sealed at one end, or small **matrasses**, an assortment

Fig. 12.

Fig. 13.

Fig. 14.

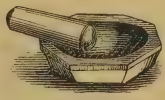


Fig. 15.

should always be kept on hand, since they are of very frequent use. Figs. 16, 17, 18, 19.

4. Of other apparatus, the most necessary are:

An **agate mortar** 50 to 60 mm. diameter, with pestle of the same material. Fig. 15.

Forceps with **platinum points.**

Forceps of steel.

A pair of **cutting pliers** for taking small pieces from a mineral specimen.

A small **hammer** and **anvil**, both of steel and well polished.

A three-cornered **file** for cutting glass tubes, trying the hardness of minerals, etc.

A small **magnet**.

Fig. 16.

Fig. 17.

Fig. 18.

Fig. 19.

A **magnifying-glass** or **lens**.

Coal-borers. Figs. 20, 21, 22.

A set of **watch-glasses**, which are very convenient for the reception of the assay-piece, the metallic globules, etc.

Pieces of **colored glass**, about 12 cm. long and 5 cm. wide; a blue one, colored with cobalt; a violet, colored with manganese; a red, colored with copper; and a green, with iron and copper.

A hollow **glass prism**, filled with indigo solution. Fig. 23.

This prism is made of plate glass, and filled with a solution prepared by dissolving one part of indigo in eight parts of fuming sulphuric acid, adding fifteen hundred to two thousand parts of water, and filtering. In practice the prism is held close to the eye and moved horizontally, so as to allow the light of the colored flame to reach the eye through successively thicker portions of the absorbing medium.

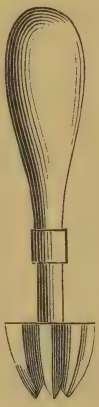


Fig. 20.

Fig. 21.

Fig. 22.

Another form of prism, somewhat cheaper and more convenient, is shown in Fig. 24.

5. Reagents. **Sodium carbonate, borax,** and **salt of**

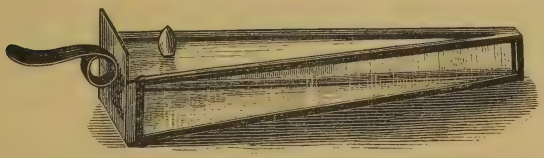


Fig. 23.

phosphorus are the most important, but there are others which, though not so extensively used, still are indispensable for the detection of certain substances; others, the use of which is very limited, are omitted in this list. All should be as pure as possible.

Sodium carbonate, Na_2CO_3. The disodium carbonate or the monosodium, $NaHCO_3$, may be used. It must be perfectly free from sulphuric acid, for the presence of which it may be tested as shown par. 121. It is used as a dissolving, decomposing, and reducing agent.

Borax, $Na_2B_4O_7 + 10H_2O$. The commercial article is purified by recrystallization, the crystals washed with distilled water, dried, and reduced to a coarse powder. Borax fuses with intumescence, forming a vitreous mass, which dissolves metallic oxides, showing characteristic colors. **Sodium thiosulphate.**

Salt of phosphorus [microcosmic salt], $NH_4NaHPO_4 + 4H_2O$. It is used for the same purposes as borax, but sometimes gives more intense or different colors with the metallic oxides. When pure it gives a glass which, on cooling, remains transparent; if this is not the case, it must be purified by recrystallization.

Fig. 24.

Neutral potassium oxalate, $K_2C_2O_4 + 2H_2O$, and **Potassium cyanide**, KCN, are more powerful reducing agents than sodium carbonate, and in many cases are to be preferred. The cyanide is usually mixed with an equal amount of sodium carbonate.

Potassium nitrate, KNO_3, **Sodium nitrate**, $NaNO_3$, and **Potassium chlorate**, $KClO_3$, serve only as oxidizing agents.

Acid potassium sulphate, $HKSO_4$. It is employed in the fused state as a coarse powder, and must be kept in a bottle provided with a ground-glass stopper. It is used as a decomposing agent, and often expels volatile

substances, which may be recognized by their odor or color.

Fused boric acid, B_2O_3. It is employed in the state of a coarse powder, especially for the detection of small quantities of copper in lead.

Fluorite, CaF_2. Must be deprived of water by ignition; must be perfectly free from boric acid, for which it may be tested as described par. 75. It is convenient to keep in a separate bottle a mixture of one part of finely-powdered fluorite, with four parts of acid potassium sulphate.

Cobalt nitrate, $Co(NO_3)_2 + 6H_2O$, in solution. It must be pure, free from alkali, iron and nickel. The solution should not be too concentrated — about one part of nitrate to ten of water; and, as only one or two drops are used at a time, it is convenient to keep it in a bottle provided with a long stopper or pipette for the purpose of dropping, Fig. 25, or, still better, in a small bulb, Fig. 26, blown from a thick, soft glass tube about 20 to 25 mm. in diameter. To fill the bulb it is gently heated and the tip placed in the solution.

Fig. 25.

Fig. 26.

After a drop has entered the bulb, it is converted into vapor by carefully heating, and the tip again placed in the liquid, which immediately flows into the bulb. It should not be more than half or two-thirds full. If now the bulb is inverted and held in the warm hand, the solution is forced out by the expansion of the air. It is used for the detection of earths and metallic oxides, which give

characteristic colors on being moistened and heated with it.

Nickel oxalate. It must be perfectly free from iron and cobalt; it is tested with borax, with which it ought to produce a pure brown glass.

Hydrochloric acid, HCl, is used for the decomposition of carbonates, for conversion of substances into chlorides, in testing flame-coloration, and, in connection with zinc, for the detection of some of the rare metals.

Nitric acid, HNO_3, is used in the separation of silver from gold.

Sulphuric acid, H_2SO_4. Pure concentrated, for various purposes, especially testing for flame-colors.

Glycerin, for detection of boric acid, as proposed by Iles, for decomposition of silicates to extract their alkalies, for spectroscopic work, and as a general laboratory reagent when mixed with two parts of HCl, as proposed by Leeds.

Copper oxide, CuO. It is best prepared by igniting the dried nitrate in a porcelain dish.

Silver chloride, AgCl. It is prepared by precipitating a solution of silver nitrate with hydrochloric acid, washing the precipitate, and making it into a thick paste with water, which is kept in a small glass-stoppered bottle. This reagent should not be used with platinum wire, since the silver fuses with the platinum to an alloy; fine iron wire is in this case substituted for the platinum. For each experiment a fresh hook should be made. It is used for intensifying the flame-coloration.

Lead. It is easily obtained pure by decomposing a solution of the acetate by metallic zinc; the precipitate is repeatedly washed with water and then dried between filter papers.

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Iron. In the shape of fine wire; used for reductions in the wet way.

Tin. Usually in the shape of foil, which is cut into strips and rolled up tightly into small long pellets. If applied to a bead containing a metallic oxide, and heated in the reducing flame, it acts as a powerful reducing agent.

Magnesium wire, in short pieces, for the detection of phosphoric acid.

Zinc, granulated, to be used with hydrochloric acid for the detection of rare metals whose solutions are reduced by the nascent hydrogen, giving characteristic changes of color.

Silver, foil or coin, for testing sulphur compounds.

Gold, in small grains, 50 to 60 mgrs., to use in testing for nickel and cobalt.

Bone-ash. In the state of very fine powder, for cupellation.

Test Papers. Blue and red litmus paper for the detection of acids and bases, Brazil-wood paper for the detection of fluorine, and turmeric paper for the alkalies, boric, and molybdic acids.

6. If the analytical research is strictly confined to blowpipe operations, the above reagents are sufficient; but if, as is sometimes advantageously done, some simple operations of the humid method of chemical analysis are called to aid, the list must be somewhat extended. The most important of these reagents are: potassium hydrate, ammonium hydrate, ammonium chloride, ammonium carbonate, ammonium oxalate, ammonium sulphide, ammonium molybdate, potassium ferrocyanide, potassium ferricyanide, platinum dichloride, lead acetate, alcohol, and distilled water.

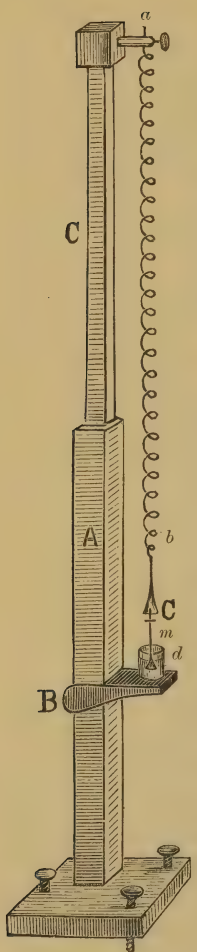

Fig. 27.

Also the following apparatus: test-tubes and test-tube rack, small porcelain dishes, small beaker glasses, glass funnels, filter stand, filter paper, platinum crucible, glass rods, a good balance or apparatus for the determination of the specific gravity of minerals and other substances. Jolly's spring balance is very convenient, and gives accurate results.

JOLLY'S SPRING BALANCE.

A wire wound in a spiral form is suspended at *a*, and has attached at its lower end, *b*, two pans, *c* and *d*. The pan *d* dips into water. The vessel containing the water, in which the pan is suspended, is placed upon a shelf, which may be moved up or down on the standard of the balance. A mark at *m* shows the extension of the spiral on the mirror scale, which is also attached to the standard. In reading, the mark is made to cover the reflection on the mirror.

If weights increasing a tenth of a gram are added successively to the pan in the air, it is found that the extension of the wire is in proportion to the weight added. Conically wound wire, with its greatest diameter at *a* and its smallest at *b*, shows precisely the relation between the size of the load and the extension of the spiral.

The manner of using the balance is extremely simple. Before the substance is placed on the pan, the place of the mark is observed on the scale. A known weight is then placed on the upper pan, and the shelf, B, moved down as far as necessary—so far that, with the consequent extension of the spiral, the pan *d* will again sink into the water, when a second reading is made. The difference in these figures gives the number of divisions on the scale over which the spiral has been made to pass by the weight. If it is found, for example, that with a weight of one gram the extension of the spiral is 122.2 divisions, while with some substance, as a piece of mineral, the extension is only 54.4, the absolute weight of the substance will be $\frac{54.4}{122.2} = 0.445$.

If, however, the absolute weight is not desired, only the specific, it is not necessary to express the absolute weight in grams. Three readings are made: first, with empty pan; second, with substance placed on the upper pan; and the third after placing the same substance on the pan under water. The difference between the first two gives the absolute weight, expressed in divisions of the scale, and the difference in the last two gives the weight of the displaced water. The quotient of these differences is therefore the specific weight. If the mark with empty pans stands at 64.2, and with the substance placed in the upper pan at 275.3, and with the same substance in lower pan at 220.8, then the absolute weight is $275.3 - 64.2 = 211.1$, and loss of weight in water is $275.3 - 220.8 = 54.5$. Specific weight will be $\frac{211.1}{54.5} = 3.85$. The second decimal is not always certain, but by proper arrangement of the spiral is found as reliable as the ordinary balance.

If the specific weight of a fluid is to be determined,

both pans are taken off, and in place of them a glass of about 1 cc. in size is suspended by a fine platinum wire. The loss of weight in water and in other liquids is shown by the scale, as in the former case.

As shown in the drawing, the shelf, B, is attached to the standard, A. The movable standard, C, has the same length as A, can be raised or lowered, and made fast at any point. C is drawn out, according to the length of the spiral, so far that the mark with the pans empty stands opposite one of the upper divisions of the scale, which, to show the whole extension of the spiral, must be at least 600 mm. long.

Every spiral at first shows a little elasticity, which grows less, and which during any one experiment amounts to really nothing.

CHAPTER II.

OF THE FLAME, AND GENERAL ROUTINE OF BLOWPIPE ANALYSIS.

THE flame of a candle consists of three distinct parts—the dark central zone or supply of unburnt gas surrounding the wick; the luminous zone or area of incomplete combustion; and the non-luminous zone or mantle of complete combustion. (Fig. 28.) In this outer zone the supply of oxygen is greatest, all the carbon is at once burned, and the flame becomes non-luminous. The effect of producing a complete combustion at once throughout the flame is seen in the Bunsen gas-lamp or burner. In this lamp (see Fig. 4) the gas issues from a small central burner, and, passing up the tube, draws air with it through the holes at the bottom of the tube; the mixture of air and gas can be lighted at the top of the tube, where it burns with a non-luminous flame. If the holes be closed, the gas alone burns with the ordinary bright flame. The blowpipe flame may also be divided into two distinct parts—the *oxidizing* flame, where there is excess of oxygen, and the *reducing* flame, where there is excess of carbon—and these are distinguished by the same properties as the outer, and inner or luminous, zone of the candle-flame.

Fig. 28.

To produce the *oxidizing* flame (Fig. 29), the stream of gas should not be too strong. The jet of the blowpipe is placed just within the flame, near the slit in the tube, so that a *strong* current of air is thoroughly mixed with the gas, which forms an inner long blue flame, *a b*. The hottest part of the flame is just before the apex of

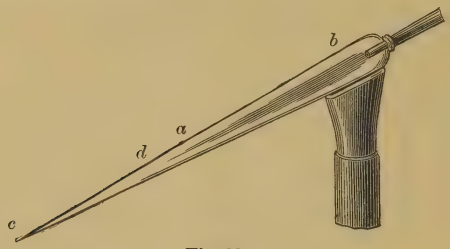

Fig. 29.

this blue cone, *d*, where the combustion of the gases is most complete. For fusion, substances are exposed to this part, but for oxidation are placed a little beyond the apex, exposed to the air.

The *reducing* flame (Fig. 30) is produced by so placing

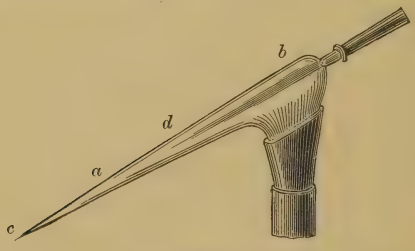

Fig. 30.

the blowpipe that the jet just reaches the flame a little above the slit, and a *gentle* current of air made to pass a little higher above the tube than in Fig. 29. The whole

flame now appears as a long, luminous cone, *a b*, being partially charged with glowing carbon surrounded with a pale-blue mantle, which extends to *c*. The most active part of the flame lies between *a* and *d*, somewhat nearer *a*. Any reducible metallic oxide placed at this point will be deoxidized or reduced, on account of the tendency of the free carbon in the flame to combine with the oxygen. It is often found necessary to maintain the reducing flame for a considerable length of time, and that the substance should be completely surrounded by it, in order to obtain the desired results. On this account a little more practice is required for this flame than for the oxidizing.

The blast should be produced with the cheek-muscles alone, and not with the lungs. The trumpet-shaped mouth-piece is pressed against the lips, and breathing is effected through the nostrils. In this way a constant and regular blast may be produced, and, after a little practice, without any perceptible exertion or weariness.

7. On examining a substance before the blowpipe with a view to determine its nature, or to ascertain the presence or absence of certain matter, it is advisable to follow a systematic course, composed of a series of operations, and to attentively observe the changes which the body undergoes under the influence of the various agents which are brought to act upon it. The various operations to which the assay is submitted are so many questions, to which the phenomena we observe constitute so many answers; and from their appearance or non-appearance we are able to draw definite conclusions as to the nature of the substance under examination.

The following order, and the rules to be observed

in the execution of the various operations, are essentially the same as first pointed out and laid down by Berzelius.

(1.) Examination in a glass tube sealed at one end or a matrass. (Figs. 18 and 19.)

(2.) Examination in a straight or slightly-bent glass tube open at both ends. (Figs. 16 and 17.)

(3.) Examination on charcoal or aluminium foil by itself.

(4.) Examination with reagents—borax, salt of phosphorus, sodium carbonate, sodium thiosulphate, acid potassium sulphate, cobalt nitrate solution, and zinc with hydrochloric acid.

(5.) Examination in the platinum-pointed forceps, or on platinum wire by itself, for the determination of fusibility and flame-coloration.

Regarding the size of the assay, a piece the size of a mustard-seed will generally be found sufficient, larger pieces, without showing the reaction more distinctly, requiring more time and labor. In some cases, however, it is advantageous to employ a greater quantity, especially for reductions or for heating in a glass tube; for the larger the metallic globule, and the greater the amount of the sublimate produced, the more readily can its nature be ascertained. A portion of the original substance should be reserved for confirmatory tests or for examination in case of accident.

It is a good plan to place the lamp on a large piece of white paper with upturned edges, or on a bright tin plate, so that if a globule or portion of the specimen is dropped, it may be easily found.

EXAMINATION IN A GLASS TUBE CLOSED AT ONE END OR A MATRASS.

8. The substance is introduced into a small glass tube sealed at one end or into a small matrass, and heat applied by means of a gas- or spirit-lamp. The heat must at first be gentle, but may be gradually raised to redness if necessary. By this treatment we learn whether—

I. THE SUBSTANCE IS ENTIRELY OR PARTIALLY VOLATILE.

Among the phenomena to be observed, the following are deserving of particular attention:

9. (1.) **Water is given off**, which partly escapes and partly condenses in the colder portion of the tube. This points to the presence of a salt containing water of crystallization* [No. 46], to the presence of a hydrate, or to salts which contain water mechanically inclosed between the laminæ of the crystals [No. 41]; in this case the substance usually decrepitates. The drops of condensed water are to be examined with test-paper; an alkaline reaction denotes the presence of ammonia, and an acid reaction the presence of some volatile acid, as sulphuric, nitric, hydrochloric, hydrofluoric, etc.

10. (2.) **Gas or vapor is given off.** Those of most usual occurrence are:

a. Oxygen, easily recognized by placing a small piece of coal upon the assay, which burns brilliantly on being heated; points to the presence of a peroxide, nitrate,

* The numbers refer to the list of substances at the beginning of the book, page 16.

chlorate, bromate or iodate [No. 42]. If the quantity of the substance is very small, add a very little sodium chloride and sulphuric acid. On being warmed, in place of the oxygen, chlorine is set free, and is recognized by its smell and bleaching action on blue litmus paper.

b. Sulphur dioxide, easily recognized by its peculiar odor and action on blue litmus paper; indicates the presence of a sulphate or sulphite [No. 46].

c. Sulphuretted hydrogen, recognized by its peculiar odor; indicates the presence of sulphides containing water.

d. Nitrogen tetroxide, recognized by its deep orange-red color and acid reaction; indicates the presence of a nitrite or nitrate [No. 43].

e. Carbon monoxide, which burns with a blue flame; indicates oxalates or formates. In the latter case the substance blackens.

f. Carbon dioxide, recognized by causing a turbidity in a drop of lime-water suspended from the convex side of a watch-glass and exposed to the escaping gas; points to the presence of a carbonate or the oxalate of a reducible metallic oxide.

g. Cyanogen, recognized by its peculiar odor and by burning with a crimson flame; indicates the presence of a cyanogen compound.

h. Ammonia, recognized by its odor and alkaline reaction; indicates the presence of an ammoniacal salt or of an organic nitrogenous substance; in the latter case the mass usually blackens, and evolves at the same time either cyanogen or empyreumatic oils of offensive odor [No. 34].

i. Hydrofluoric acid changes the color of test-paper,

and also attacks the glass just above the assay and makes it dull.

j. Chlorine, indicated by greenish-yellow fumes and its odor.

k. Iodine is indicated by violent fumes and its peculiar odor, and, if the amount is not too small, will form a steel-gray sublimate.

l. Bromine, indicated by its orange-colored vapor and its pungent odor.

11. (3.) **A sublimate is formed.**

(α.) *WHITE SUBLIMATES* are formed by:

a. Ammonium salts. On removing the sublimate from the tube, placing it on a watch-glass, adding a drop of potassium hydrate and applying heat, ammonia is evolved [No. 37].

b. Mercury chlorides. The mercurous chloride sublimes without previous fusion; the mercuric chloride fuses first, then sublimes; the sublimate is yellow while hot, but becomes white on cooling [Nos. 49 and 50]. Mercuric oxide forms globules of mercury.

c. Antimony trioxide. It fuses first to a yellow liquid, then sublimes; the sublimate consists of lustrous needle-shaped crystals [No. 19].

d. Arsenic trioxide. The sublimate consists of octahedral crystals [No. 31].

e. Tellurium dioxide shows a reaction similar to that of antimony trioxide, but requires a much higher temperature; the sublimate is amorphous.

f. Osmium tetroxide forms a sublimate of white drops, with a pungent, disagreeable odor.

(β.) *BLACK OR GRAY SUBLIMATES* with metallic lustre, or metallic mirrors, are formed by:

a. Arsenic, and *arsenides* containing more than one

equivalent of arsenic to two of metal; also, some sulph-arsenides [No. 74]; cutting the tube below the sublimate and exposing the mirror to gentle heat in the gas-flame, the garlic odor of arsenic is perceived.

b. Mercury, amalgams, and some mercury salts; the sublimate consists of minute globules of mercury, which, by friction with a piece of copper wire, readily unite to larger globules [No. 9].

c. Some alloys of *Cadmium.*

d. Tellurium, only at a very high temperature; the sublimate consists of small globules, which solidify on cooling.

(*γ.*) *COLORED SUBLIMATES* are formed by:

a. Sulphur, and *Sulphides* containing a large amount of sulphur; the sublimate is deep-yellow to brownish-red while hot, but pure sulphur-yellow when cold [No. 72].

b. Antimony sulphides, alone or in combination with other sulphides; the sublimate forms only at a very high temperature, and is deposited at a short distance from the assay-piece; it is black while hot, reddish-brown when cold [No. 71].

c. Arsenic sulphides and some compounds of metallic sulphides with arsenides; the sublimate is dark brownish-red while hot, but reddish-yellow to red when cold [No. 77].

d. Cinnabar. The sublimate is black, without lustre, and sometimes yields a red powder on being rubbed or if scratched with a knife [No. 78].

e. Selenium and some *selenides;* the sublimate appears only at a high temperature, is of a reddish or black color, and yields a dark-red powder; at the open end of the tube the peculiar odor of selenium (resembling rotten horse-radish) is perceived [No. 84].

II. THE SUBSTANCE CHANGES WITHOUT VOLATILIZATION.

12. Many substances under this treatment suffer physical changes without being affected in their chemical constitution. The most important of these physical changes are.

1. **Change of color:**

(*a.*) From white to yellow, and white again on cooling; zinc oxide [No. 22].

(*b.*) From white to yellowish-brown, dirty pale yellow on cooling; tin oxide [No. 23].

(*c.*) From white to brownish-red, yellow when cold, and fusible at a red heat; lead oxide [No. 69].

(*d.*) From white to orange-yellow or reddish-brown, pale yellow when cold, and fusible at a bright red heat; bismuth oxide [No. 20].

(*e.*) From red to black, and red again on cooling; ferric oxide (*non-volatile*) [No. 24].

(*f.*) From red to black, red when cold; mercuric oxide (*volatile*).

2. **Carbonization:** organic substances.

3. **Fusion:** some alkaline salts.

4. **Decrepitation:** alkaline chlorides and very many minerals.

5. **Phosphorescence:** alkaline earths, earths, tin oxide, zinc oxide, and many minerals.

EXAMINATION IN A GLASS TUBE OPEN AT BOTH ENDS.

13. A fragment of the substance, sometimes in form of a powder, is introduced into the tube to a depth of 10 or 12 mm., the end to which it lies nearest slightly inclined, and heat applied. The air contained in the

tube becomes heated; it rises, escapes from the upper end, and fresh air enters from below. In this manner a calcination is effected, and many substances which remained unchanged when heated in a matrass yield sublimates or gaseous products when subjected to this treatment, owing to the formation of volatile oxides.

By this means the presence of the following substances can be detected:

14. Sulphur. Sulphur dioxide is evolved, which is characterized by its peculiar odor and action on moistened blue litmus paper [No. 72].

15. Arsenic. If present in sufficient quantity it yields a white and very volatile sublimate of arsenic trioxide, consisting of minute octahedral crystals; by application of gentle heat it may be driven from one place to another [No. 74].

16. Antimony. White fumes of antimony trioxide are given out, which partly escape and partly condense in the upper part of the tube. The sublimate is a white powder, and may, if consisting of pure antimony trioxide, be volatilized by heat. In most cases, however, the oxidation proceeds farther, and antimony tetroxide, a non-volatile white powder, is formed [No. 1].

17. Bismuth. When not combined with sulphur, it is converted into oxide, which condenses at a short distance from the assay, and which by heat may be fused to brownish globules, which on cooling become pale yellow [No. 4].

18. Mercury and **Amalgams** yield sublimates of metallic mercury in small globules [No. 9].

19. Tellurium and **Tellurides.** Tellurium dioxide is produced, which condenses in the upper part of the tube to a white non-volatile powder; on application of heat

it fuses to colorless globules, thus distinguishing it from antimony [No. 85].

20. Selenium and **Selenides** evolve a gaseous oxide of a peculiar odor, resembling that of rotten horse-radish [No. 84]; a sublimate of selenium, gray near the assay and red at a distance, is sometimes formed.

EXAMINATION ON CHARCOAL OR ALUMINIUM FOIL.

21. A small quantity of the substance is placed in a shallow cavity near to the edge of the coal, which is held slightly inclined, so that when the flame is directed upon it, the coating, if one is formed, is deposited on the coal. Its behavior in both flames should be observed. If the substance is in the form of a powder, or if it decrepitates so that it must be reduced to a powder, it may be moistened with water and then packed into the cavity. Or a small grain of borax may be first fused in the cavity, and the powder or fragment placed upon it while the borax is still in the melted state.

Should aluminium foil be used in place of charcoal, the substance is first heated on the bare foil, and afterward on the small piece of coal described on page 22. In this way the readily volatile metals, together with the difficultly ones, may often be determined. The coatings are thicker on the foil than on the coal because the support remains at a lower temperature and the vapors condense upon the vertical portion. The coatings are treated with the reducing flame and the peroxidizing flame. The latter is obtained by bringing a good oxidizing flame within one or two inches of the coating obtained.

The following phenomena should be considered:

22. (1.) **Fusibility.** The *easily-fusible non-metal-*

lic compounds are most of the alkaline salts and some of the salts of the alkaline earths, as barium and strontium hydrates, and, after continued heating, their carbonates and sulphates. Their residues, after ignition, have an alkaline reaction, turning moist turmeric paper brown. Some are volatile and cover the charcoal with a coating (see page 52 (1, 2, 3).

The *infusible without flame-coloration* are compounds of the earths and of the alkaline earths, which glow intensely when heated, and may be further tested with cobalt solution; also silica and many silicates.

The *infusible with change of color* are the oxides of zinc, tin, titanium, niobium, tantalum, tungsten, which take on a yellow color while hot.

The *easily-fusible metals* are antimony, lead, bismuth, cadmium, zinc, tin, tellurium, thallium, and indium.

The *somewhat difficultly fusible* are gold, silver, and copper.

The *infusible* are iron, cobalt, nickel, molybdenum, platinum, iridium, osmium, palladium, rhodium, and tungsten.

(2.) **Deflagration.** Nitrates, chlorates, iodates, bromates.

(3.) **Decrepitation.** Sodium chloride, other haloid salts, substances containing water, and many minerals.

(4.) **Intumescence.** Substances containing water of crystallization, as borates, alums, etc.

(5.) **Odor.** It is usually given off as soon as the flame is directed upon the substance. Smell of sulphur dioxide indicates sulphur or sulphides; odor of garlic, arsenic; odor of rotten horse-radish, selenium.

(6.) **Color of flame** may be better seen when plat-

inum wire or the platinum-pointed forceps are used for support and the substance placed in the Bunsen flame (see pars. 56–61 and Chap. IV.).

23. (7.) **Reduction to metal and formation of a coating.** Some metallic oxides are reduced to metal when heated on charcoal, some are wholly or partially volatilized, the vapor passing off or forming a coating upon the charcoal. Oftentimes a considerable amount of ash is formed upon the coal where the flame strikes it, which may be mistaken for a coating.

As already observed, most of the metallic oxides can be easily reduced by the reducing flame alone, others with difficulty, and some not at all. The latter, in a fine state of division, may be mixed with sodium carbonate or with a mixture of this with potassium cyanide, or potassium oxalate if it be used, and then treated in the reducing flame. The reduction is generally easily accomplished.

The above reagents do not prevent the formation of a coating.

(*A.*) *REDUCED METAL WITHOUT COATING.*

24. Gold, silver, and copper form malleable beads with metallic lustre. Molybdenum, tungsten, platinum, palladium, iridium, rhodium, iron, nickel, cobalt, give a gray infusible powder, which, in case of the last three substances, is magnetic.

To separate the reduced metal, the fused mass is cut out from the charcoal, ground with water in a mortar, and the lighter particles of coal are poured off with the water. The malleable metals remain in flattened, shining scales, and the brittle ones as metallic powder. Silver, gold, and copper may be distinguished by their colors.

The other metals are determined by further treatment with borax and salt of phosphorus.

(*B.*) *REDUCED METAL WITH COATING.*

25. Antimony. It fuses readily and covers the charcoal with white oxide; the ring is not so far distant from the assay-piece as in the case of arsenic; it may be driven about by the oxidizing flame and made to disappear with the reducing flame, which it colors a very pale green, but is not so volatile as that of arsenic, and does not emit an alliaceous odor. Metallic antimony, when fused on charcoal and heated to redness, remains a considerable time in a state of ignition without the aid of the blowpipe, disengaging, at the same time, a thick white smoke, which is partly deposited on the charcoal around the metallic globule in white crystals of a pearly lustre [No. 1].

On aluminium foil the coating near to the assay is yellow, farther away pure white, and still farther off bluish-white. Most minerals yield antimony on the bare plate. The peroxidizing flame darkens the yellow color momentarily, whilst the reducing flame instantly blackens all parts of the coating.

26. Bismuth. It fuses readily in both flames and covers the charcoal with oxide, which is dark orange-yellow while hot and lemon-yellow when cold. The yellow coating is usually surrounded by a yellowish-white ring, consisting of bismuth carbonate. The coating is somewhat nearer the assay than that of antimony; it may be driven away by both flames, but, unlike antimony and lead, does not impart any color to the reducing flame during the operation [No. 4].

On the aluminium foil little or no coating is obtained, but on the charcoal support a coating is produced

which is yellow nearest the test-piece, passing into orange, and this into brown. Upon the ledge also a yellow coating is formed. The oxidizing flame darkens the color of the yellow and orange portions temporarily (compare *Lead*), whilst the reducing flame blackens both.

27. Lead. It fuses easily and coats the charcoal in both flames with oxide, which is dark lemon-yellow while hot and sulphur-yellow when cold, with a border of bluish-white which consists of carbonate. The coating is found at the same distance from the assay as that of bismuth; it may be driven away by either flame; when played upon with the reducing flame it imparts to it an azure-blue color [No. 3].

On aluminium foil a coating is obtained only on using a charcoal support, as in the case of bismuth. The coating is coffee-brown, surrounding a pale yellow ring; on the ledge it is white. The yellow and white parts become brown in the oxidizing flame, retaining this color on cooling, whilst the brown color, in the case of bismuth, disappears again on cooling. In the reducing flame all parts become black.

28. Tin. It fuses readily; exposed to the oxidizing flame, it is converted into oxide, which may be blown away and thus be made to appear as a coating; it is always found closely surrounding the assay-piece, is slightly yellow and luminous while hot, white when cold, and non-volatile in both flames. Exposed to the reducing flame, the molten metal retains its bright metallic aspect [No. 7].

On aluminium foil a faint white coating is obtained by long heating on the charcoal support. The reaction on the support is the same as that on charcoal, just described.

29. Silver. When exposed for a long time to the action of the reducing flame it yields a slight dark-red coating of oxide [No. 8]. If the silver contains lead or antimony, a yellow or white coating appears before the red one; or if lead and antimony are present at the same time, the coating has a bright rose-color.

On aluminium plate a brown coating, shading off into a lighter rim having a reddish tinge, is obtained. Near the glowing edge of the charcoal is a narrow whitish strip with a faint pink tinge. The oxidizing flame darkens all parts, whilst the reducing flame produces a circle of white having the appearance of frosted silver. The rose-colored coating produced by silver in presence of antimony, coming out beautifully on aluminium plate, is, however, more characteristic.

30. Gold. On charcoal fuses, but gives no coating.

On aluminium plate a coating is produced after heating for some time with charcoal support. The gold is volatilized, and near the charcoal a yellow film of gilding is deposited on the plate; beyond this is a strip of violet, and dotted all over are little specks of gold carried away mechanically.

31. Thallium. It fuses easily and coats the charcoal with white oxide, which is driven away by slight warming; on contact with the flame this latter acquires a green coloration, and the oxide disappears. The fused bead, which also colors the flame green, remains fluid for a considerable time after the flame is removed, and sometimes deposits a brown coating in its neighborhood.

On aluminium plate a copious white coating is first produced, which, as the temperature of the plate increases, is followed by a brownish one. In the oxidizing flame the white part instantly turns reddish-brown.

This change takes place more quickly than with lead, and the color produced is very different. In the reducing flame all parts become black, and in the thickest portions little black beads can be seen with a lens.

32. Indium. It fuses readily, forming a coating very near the assay, which is dark yellow while hot and yellowish white when cold. It may be driven off with difficulty by the reducing flame, to which it gives a clear violet tint.

(*C.*) *COATING WITHOUT REDUCED METAL.*

33. Arsenic. It is volatilized without previous fusion; the charcoal is covered with a white coating, which is far distant from the assay-piece, and which is produced by both the oxidizing flame and reducing flame; the coating is very volatile, and is easily driven away by the blowpipe flame, to which it imparts a light-blue color, emitting the peculiar alliaceous odor characteristic of arsenic [No. 2].

On aluminium foil without charcoal support a white coating is obtained, and a black stain is produced under the test-piece. On the charcoal support, when much arsenic is present, there is also a grayish-black coating, together with large black stains on the ledge. In the oxidizing flame the white portion is unchanged, but volatilizes rapidly as the plate gets hot. The gray and black portions are somewhat whitened and partly removed, but dark stains remain. The reducing flame volatilizes the coating rapidly, and the arsenic smell is very clearly perceptible.

34. Zinc. It fuses readily; exposed to the oxidizing flame it burns with an intensely luminous greenish-white flame, emitting at the same time a thick white smoke, which, partly condensing on the charcoal, rather near

the assay, covers it with oxide, yellow while hot and white when cold. The coating, when played upon with the oxidizing flame, becomes luminous, but does not disappear [No. 6].

On aluminium foil without charcoal support, scarcely any coating is obtained. On a charcoal support a black film is produced as soon as the metal begins to burn, which directly gives place to the white oxide film. The oxidizing flame and reducing flame have no action on the coating. Minerals containing zinc do not give the black coating.

35. Cadmium. It fuses readily, and exposed to the oxidizing flame it burns with a dark-yellow flame, emitting brown fumes of oxide, which cover the charcoal around and near the assay. This coating is very characteristic; it is, when cold, of a reddish-brown color; in thin layers, orange-yellow; it is easily volatilized by both flames without imparting a color to them. Beyond the coating a variegated border is sometimes seen [No. 5].

On aluminium foil a dark brown, almost black film is obtained, which is not affected by either the oxidizing flame or reducing flame. On the edges of the charcoal support a little reddish-brown oxide is usually deposited.

36. Selenium. It fuses very readily in both flames with disengagement of brown fumes; at a short distance from the assay a steel-gray coating of a feeble metallic lustre is deposited; played upon with the reducing flame, it disappears with emission of a strong odor of rotten horse-radish, at the same time imparting to the flame a fine blue color [No. 84].

On aluminium foil with charcoal support a red coating is formed, together with some brown and white film. The

oxidizing flame whitens the red and brown parts, whilst the reducing flame gives to all parts a deep brown color.

37. Tellurium. It fuses very readily and coats the charcoal in both flames with tellurium dioxide; the coating is not very far distant from the assay; it is of a white color with a red or dark-yellow edge; played upon with the reducing flame it disappears, imparting to the flame a green tinge.

On aluminium foil, with and without the charcoal support, a strong coating is formed close to the assay, which is brown in thin films. Where the deposit is thickest a white layer of tellurium dioxide forms on short exposure to the oxidizing flame. The reducing flame turns all parts black; on longer blowing the coating disappears, the flame becoming tinged with green.

38. Molybdenum. The metal, a grayish infusible powder, oxidizes in the oxidizing flame and gives a partly crystalline coating, which is yellow whilst hot and white when cold. By momentary exposure to the flame the coating becomes of a beautiful dark-blue color (molybdic molybdate); by longer heating it becomes dark copper-red, with metallic lustre (molybdenum dioxide).

On aluminium plate the coating (best obtained from molybdenite or ammonium molybdate) is produced without charcoal and is light-yellow with white film. The oxidizing flame darkens the color somewhat, whilst the reducing flame by momentary contact produces a beautiful blue coloration.

Besides the above-named elements, there are other substances that yield white coatings which may, with few exceptions, be driven away when played upon by the oxidizing flame, and which bear some resemblance to those described. The most important bodies of this kind are the following:

(1.) The sulphides of the alkalies, of lead, bismuth, antimony, zinc (coating non-volatile), tin (coating non-volatile), and the chlorine, iodine, and bromine compounds of ammonium, mercury, and antimony: they coat the charcoal without previously fusing or sinking into the support.

(2.) The compounds of the alkalies with chlorine, bromine, iodine, and sulphuric acid; they fuse and sink into the charcoal before they evaporate.

(3.) The chlorine, bromine, and iodine compounds of lead, tin, bismuth, zinc, and cadmium, which fuse but do not sink into the charcoal before they coat it.

EXAMINATION WITH BORAX AND SALT OF PHOSPHORUS.

39. The examination of the assay with borax and salt of phosphorus is eminently adapted to detect the presence of metallic oxides, a great number of them possessing the property of being at a high temperature dissolved by these fluxes with a characteristic color. Unoxidized metals and metallic sulphides, arsenides, etc., differ in this respect very materially from the pure oxides; hence it is necessary before performing the experiment to convert all such substances into oxides. This is effected by calcination, or roasting on charcoal or in an open glass tube. The finely-powdered assay is placed on charcoal and alternately treated with the oxidizing flame and reducing flame, and this process is repeated until the substance no longer emits, while in the incandescent state, the odor of sulphur or arsenic. The heat must never be raised so high as to cause fusion, and between every two succeeding calcinations the assay should be taken from the charcoal and freshly powdered.

The experiment with borax is generally made on platinum wire, where the color of the bead is more readily observed; charcoal is used only in such cases where the substance under examination contains metallic oxides which are easily reduced to metal which attacks platinum. It is not sufficient to observe the color of the bead after cooling, but all changes of color which take place during the action of the flame, and through all the various stages of cooling, should be carefully noticed.

40. Flaming. In many cases when a transparent bead is intermittently heated in the flame, or is repeatedly taken out of the flame, peculiar effects are obtained. This operation has received the name of "flaming." Clear beads frequently become opaque, milk-white, or even colored. This depends on the fact that certain compounds which dissolve at a high temperature separate out on being heated to a somewhat lower temperature, appearing as peculiar crystals, which are sufficiently well formed in most cases to be visible under the microscope when the bead has been flattened whilst hot, or when it has been dissolved in dilute acid so as to isolate the crystals.

41. The behavior of the metallic oxides with borax and salt of phosphorus is shown in the following tables. They are arranged according to the color yielded by the hot bead when acted on by the oxidizing flame, and the reactions of the oxidizing and reducing flames are given in the same line. It may be here remarked, salt of phosphorus beads are often more beautiful than those of borax, and are occasionally different in color.

The behavior of the metallic oxides to these reagents is also given in the third and fourth columns of the table at the end of Chapter IV., where the metals are arranged in alphabetical order.

BEHAVIOR OF METALLIC OXIDES WITH BORAX.

Contractions: fl. = by flaming; c. bl. = continued blowing; s. b. = saturated bead.

In the Oxidizing Flame.		In the Reducing Flame.		Indication.
Hot.	*Cold.*	*Hot.*	*Cold.*	
colorless	colorless	colorless	colorless	Silica
"	"	"	"	Alumina
"	"	"	"	Tin oxide
"	colorless; fl., opaque	gray; c. bl., colorless	gray; c. bl., colorless	Silver oxide
"	"	"	"	Tellurium dioxide
"	"	colorless	colorless; fl., opaque	Baryta
"	"	"	"	Strontia
"	"	"	"	Lime
"	"	"	"	Magnesia
"	"	"	"	Glucina
"	"	"	"	Yttria
"	"	"	"	Zirconia
"	"	"	"	Thoria
"	"	"	"	Lanthanum oxide
"	"	"	"	Tantalum pentoxide
"	colorless	s. b., rose-red	s. b., rose-red	Didymium oxide
"	colorless; fl., opaque	colorless; s. b., gray	colorless; s. b., gray	Niobium pentoxide
colorless; s. b., yellow	"	yellow to brown	yellow to brown; s. b. fl., blue	Titanium dioxide

BEHAVIOR WITH BORAX—*Continued.*

In the Oxidizing Flame.		In the Reducing Flame.		Indication.
Hot.	*Cold.*	*Hot.*	*Cold.*	
colorless; s. b., yellow	colorless; s. b., enamel-white	yellow	yellowish-brown	Tungsten trioxide
yellowish	"	gray; c. bl., colorless	gray; c. bl., colorless	Zinc oxide
"	"	"	"	Cadmium oxide
"	colorless	"	"	Antimony oxide
yellow	colorless; fl., opaque	"	"	Lead oxide
"	colorless; s. b., yellow and opalescent	"	"	Bismuth oxide
"	greenish-yellow	brownish	emerald-green	Vanadium pentoxide
yellow to red	colorless to yellow	green	bottle-green	Iron oxide
"	colorless to yellow; fl., enamel-like	"	bottle-green; s. b., fl., black	Uranium oxide
"	"	colorless	colorless; s. b., enamel-white	Cerium oxide
"	colorless to opalescent	brown	opaque-brown *	Molybdenum trioxide
"	grass-green	green	emerald-green	Chromium oxide
violet	reddish-brown	gray; c. bl., colorless	gray; c. bl., colorless	Nickel oxide
violet: s. b., black	reddish-violet; s.b., black	colorless	colorless	Manganese oxide
blue	blue	blue	blue	Cobalt oxide
green	bluish-green	colorless	brown; c. bl., red	Copper oxide

* In a strong reducing flame black particles of molybdenum oxide appear in the yellow bead.

BEHAVIOR OF METALLIC OXIDES WITH SALT OF PHOSPHORUS.

Contractions: fl. = by flaming; c. bl. = continued blowing; s. b. = saturated bead.

In the Oxidizing Flame.		In the Reducing Flame.		Indication.
Hot.	*Cold.*	*Hot.*	*Cold.*	
silica skeleton	silica skeleton	silica skeleton	silica skeleton	Silica
colorless	colorless	colorless	colorless	Alumina
"	"	"	"	Tin oxide
"	colorless; fl, opaque	"	colorless; fl., opaque	Baryta
"	"	"	"	Strontia
"	"	"	"	Lime
"	"	"	"	Magnesia
"	"	"	"	Glucina
"	"	"	"	Yttria
"	"	"	"	Zirconia
"	"	"	"	Thoria
"	"	"	"	Lanthanum oxide
"	colorless	"	c. bl., violet	Didymium oxide
"	colorless; fl., opaque	gray; c. bl., colorless	gray; c. bl., colorless	Tellurium dioxide
colorless; s. b., yellow	colorless; s. b., milk-white	"	"	Zinc oxide
"	"	"	"	Cadmium oxide
"	"	"	"	Lead oxide
"	"	"	"	Antimony oxide

BEHAVIOR WITH SALT OF PHOSPHORUS—*Continued.*

In the Oxidizing Flame.		In the Reducing Flame.		Indication.
Hot.	*Cold.*	*Hot.*	*Cold.*	
colorless; s. b., yellow	colorless; s. b., milk-white	gray; c. bl., colorless	gray; c. bl., colorless	Bismuth oxide
"	colorless	colorless	colorless	Tantalum oxide
"	"	dirty-green	blue*	Tungsten trioxide
"	"	yellow	violet*	Titanium dioxide
"	"	blue or brown	blue or brown*	Niobium pentoxide
yellow	yellow; s. b., opalescent	gray; c. bl., colorless	gray; c. bl., colorless	Silver oxide
"	yellowish-green	dirty-green	beautiful green.	Uranium oxide
dark-yellow	light-yellow	brownish	emerald-green.	Vanadium pentoxide
yellow to red	gre en colorless to yellow or brown	yellow to red	gree nish colorless to red-dish	Iron oxide
"	colorless	colorless	colorless	Cerium oxide
reddish to brownish-red	yellow to reddish-yellow	reddish	yellow	Nickel oxide
reddish dirty-	green emerald-green	"	green	Chromium oxide
violet	violet	colorless	colorless	Manganese oxide
blue	blue	blue	blue	Cobalt oxide
green	"	dark-green	brownish-red (turbid)	Copper oxide
"	faint yellowish-green, almost colorless	dirty-green	pure green	Molybdenum trioxide

* Blood-red on addition of iron.

EXAMINATION WITH SODIUM CARBONATE.

42. The examination with soda is usually performed on charcoal in the reducing flame, and as a general rule, the flux is added successively in small portions. It is sometimes better to form the pulverized assay into a paste with moistened soda before placing it upon the coal. This is particularly necessary when the assay is to be tested for its fusibility with soda, since a great many minerals, etc. behave very differently with different quantities of the flux.

43. Instead of sodium carbonate, the *neutral potassium oxalate* or *potassium cyanide* may be advantageously used for all experiments of reduction, since these reagents exercise a more powerful reducing action than sodium carbonate. They are for this reason frequently employed when the presence of such metallic oxides is suspected whose conversion into metals requires high temperatures and the aid of a very efficient deoxidizing agent.

44. In subjecting a body to the treatment of soda, we have to direct our attention to two points.

Some substances unite with soda to fusible compounds, others form infusible compounds, and others again are not acted upon at all; in the last case the soda is absorbed by the charcoal and the assay is left unchanged. With soda form fusible compounds with effervescence:

45. Silicic acid fuses to a transparent glassy bead which, after cooling, remains transparent if the soda has not been added in too great excess [No. 51].

Titanium dioxide fuses to a transparent glassy bead which is dark-yellow while hot; on cooling becomes opaque and crystalline [No. 62].

Tungsten trioxide and **Molybdenum trioxide**, after the carbon dioxide is driven off, are absorbed by the charcoal [No. 29 and No. 30].

Tantalum pentoxide, vanadium pentoxide, and niobium pentoxide also yield fusible compounds and sink into the charcoal.

Lime, magnesia, alumina, zirconia, thoria, yttria, and glucina, as well as cerium and uranium oxides, are not attacked; they remain unchanged, whilst the soda sinks into the charcoal.

The salts of barium and strontium form with soda fusible compounds which are absorbed by the charcoal [No. 54 and 55].

Sodium carbonate is also used for the detection of:

Sulphur, *selenium*, and *tellurium compounds*, which give with it a fused mass, yielding a black, brown, or yellow stain when laid on a piece of silver and moistened with water.

Manganese and *chromium*, with the soda alone; or better, with addition of sodium nitrate, yield colored masses; the former a green mass of manganate and the latter a yellow mass of chromate.

46. The second point to be observed is the elimination of metallic matter. Of the metallic oxides, when treated with soda on charcoal in reducing flame, are reduced: the oxides of the noble metals and the oxides of arsenic, antimony, bismuth, indium, cadmium, copper, cobalt, iron, lead, mercury, nickel, tin, zinc, molybdenum, tungsten, and tellurium. Of these, arsenic and mercury vaporize so rapidly that frequently not even a coating is left on the charcoal. Antimony, bismuth, cadmium, lead, zinc, and tellurium are partly volatilized and form distinct coatings on the charcoal. The non-volatile reduced metals are found mixed up with the soda. To separate them from the adhering soda and charcoal powder, we may proceed in the following manner:

The fused mass of soda and metal, and the portion of the charcoal immediately below and around the assay, are placed in a small mortar, rubbed to powder, the powder mixed with a little water and stirred up. The heavy metallic particles settle to the bottom, part of the soda dissolves, and the charcoal powder remains suspended in the water. The liquid is carefully poured off and the residue treated repeatedly in the same manner until all foreign matter is removed. The metal remains behind as a dark heavy powder, or when the metal is ductile and easily fusible, in the shape of small flattened scales of metallic lustre. These may be examined with the magnifying-glass, and also with the magnet. If the substance under examination contains several metallic oxides, the metallic mass obtained is usually an alloy, in which the several metals may be recognized by processes to be described hereafter. It is only in some exceptional cases that separate metallic globules are obtained, for example, in substances containing iron and copper.

For a more detailed account of the behavior of the various metallic oxides under this treatment, see the second column of Tables I. and II., pages 189–215.

A list of the oxidized minerals arranged according to their fusibility and behavior with sodium carbonate may be found under its appropriate head.

EXAMINATION WITH SODIUM THIOSULPHATE.

47. All the metals precipitated by sulphuretted hydrogen in the wet way, yield the sulphide reaction in the dry way when the substance is heated with powdered sodium thiosulphate. The reagent may be applied to a borax bead, in which the substance is already dissolved, the bead being then heated in the reducing flame. This

method has, however, the disadvantages that easily-volatile substances, such as arsenic and mercury compounds, afford no reaction, and that the color imparted to the bead by the sulphide formed may easily be mistaken. Hence it is better to heat the powdered substance with the reagent in a glass tube closed at one end. After the decomposition of the thiosulphate, which is easily recognized by the odor of sulphuretted hydrogen produced, the color of the fused mass, due to the sulphide formed, is very readily seen.

In many cases the reaction is accelerated by the addition of a small quantity of oxalic acid.

As the thiosulphate contains a considerable amount of water of crystallization, the greater part of this should be previously expelled, or the glass should be held horizontally to prevent cracking, and have its mouth stopped with a little cotton-wool on first heating.

The sulphide reactions of the metals are given in the following table, together with the borax reactions. The two methods supplement each other exceedingly well:

Metallic oxide.	Reaction with $Na_2S_2O_3$.	Reaction with borax on platinum wire (the bead cold).	
		Oxidizing flame.	Reducing flame.
Antimony oxide.....	red	colorless	gray to colorless
Arsenic "	yellow	.....	.....
Bismuth "	black	colorless	gray to colorless
Cadmium "	yellow	"	"
Chromium "	green	grass-green	emerald-green
Cobalt "	black	blue	blue
Copper "	"	bluish-green	brown
Gold "	"	reduced with	out dissolving
Iron "	"	yellow	bottle-green
Lead "	"	colorless	gray to colorless
Manganese "	light-green	reddish-violet	colorless
Mercury "	black	.....	.....
Molybdenum "	brown	colorless	brown

Metallic oxide.	Reaction with $Na_2S_2O_3$.	Reaction with borax on platinum wire (the bead cold).	
		Oxidizing flame.	Reducing flame.
Nickel oxide.....	black	reddish-brown	gray to colorless
Platinum "	"	reduced with	out dissolving
Silver "	"	colorless	gray to colorless
Thallium "	"	"	colorless
Tin "	brown	"	"
Uranium "	black	yellow	bottle-green
Zinc "	white	colorless	gray to colorless

EXAMINATION WITH ACID POTASSIUM SULPHATE or CONCENTRATED SULPHURIC ACID.

48. To determine the presence of volatile acids a small quantity of the substance is heated with acid potassium sulphate or with concentrated sulphuric acid (in the latter case, however, not to the boiling-point of the acid), and the following appearances are looked for:

1. **A colored gas is evolved.**

a. Nitrogen tetroxide fumes, known by their reddish-brown color and characteristic odor; evolved from nitrates and nitrites. With nitrates the reaction is promoted by the addition of metallic copper.

b. Chlorine tetroxide; yellowish-green, odor of chlorine, bleaching litmus paper, and explosive. The tetroxide is produced from chlorates by this treatment.*

c. Iodine, from iodides, is known by its violet vapors, which color starched paper blue. Iodates* give this reaction after the addition of ferrous sulphate.

d. Bromine; reddish-brown vapor, with pungent, unpleasant odor, and turning starch-paste yellow; yielded

* The chlorates, iodates, and bromates detonate when heated on charcoal.

by bromides and bromates. The color of the vapor is best seen on looking down the tube.

2. **A colorless odorous gas is evolved.**

49. *a. Sulphur dioxide*, from sulphites and polythionates, is easily known by its odor.

b. Hydrochloric acid, from chlorides, known by its odor and by the cloud of ammonium chloride which is formed when a glass rod moistened with ammonia solution is held near to the tube.

c. Hydrofluoric acid, from fluorides, has a very pungent odor and strongly corrodes glass.

d. Sulphuretted hydrogen, from sulphides, blackens paper moistened with lead acetate.

e. Cyanic acid, from cyanates, has a characteristic pungent odor; it brings tears into the eyes, and renders lime-water turbid.

f. Acetic acid, from acetates, is known by its pungent odor, and also by yielding fragrant acetic ether on heating with sulphuric acid and alcohol.

3. **A colorless odorless gas is evolved.**

50. *a. Carbon dioxide* is expelled from the carbonates with effervescence; it renders lime-water turbid.

b. Carbon monoxide, which burns with a bluish flame, may arise from oxalates, formates, cyanides, ferrocyanides, ferricyanides.

c. Chromic acid evolves oxygen, and the liquid turns brown or green.

d. Organic acids, recognized by the blackening due to the separation of carbon.

The acids which cannot be detected by the above methods, though easily detected in other ways, are: sulphuric, phosphoric, arsenic, boric, silicic, tungstic, molybdic, and titanic. With respect to the three last named, see par. 51.

EXAMINATION WITH ZINC AND HYDROCHLORIC ACID AFTER PREVIOUS DECOMPOSITION.

51. A mixture of sodium carbonate and nitre is added to the finely-powdered assay, the mass is moistened slightly, and placed in a little spiral from about 2 to 3 mm. in diameter formed at the end of a very fine platinum wire. After fusing for a short time, the glowing mass is thrown off into a porcelain dish and digested with a little water in a test tube. Afterward a few drops of hydrochloric or sulphuric acid are added, and a strip of zinc is brought into the solution. By the reducing action of the nascent hydrogen formed, various colors are produced, as exhibited in the following list:

Molybdenum trioxide: blue, then green, finally blackish-brown.

Tungsten trioxide: blue, then copper-red.

Vanadium pentoxide: blue, then green, finally violet.

Niobium pentoxide: blue; often also brown (with strongly acid solution).

Chromium trioxide: green.

Titanium dioxide: violet.

EXAMINATION WITH COBALT SOLUTION.

52. A few substances, when moistened with a solution of cobalt nitrate and exposed to the action of the oxidizing flame, assume a peculiar color. The use of this test is, however, very limited, since the reaction can only be clearly seen in those bodies which, after having been acted upon by the oxidizing flame, present a white appearance, or nearly so. (See par. 22.)

53. Substances which are sufficiently porous to absorb a liquid are merely moistened with a drop of cobalt solu-

tion, held with the platinum-pointed forceps, and treated with the oxidizing flame. Other substances must be powdered, the powder placed on charcoal, moistened with a drop of cobalt solution, and treated as above. The color can only be distinguished after cooling. A bluish color of more or less purity, but rather dull, indicates the presence of alumina [No. 32], and a pale-reddish color (flesh-color) that of magnesia [No. 56]. It must, however, be borne in mind that the alkaline and some other silicates, when heated with cobalt solution to a temperature above their fusing point, also assume a blue color, owing to the formation of cobalt silicate. In testing for alumina, therefore, the heat must not be raised so high as to cause fusion of the assay. In testing for magnesia this precaution is not necessary; on the contrary, the color will appear the brighter and the more distinct the higher the temperature to which the assay was exposed. The alumina and magnesia reactions are prevented by the presence of colored metallic oxides, which generally produce a gray or black mass, unless present in too minute quantity.

54. Among the oxides of the heavy metals, those of zinc and tin assume characteristic colors with solution of cobalt. The reaction is best seen when the assay, alone or mixed with soda, is exposed to the reducing flame on charcoal. The ring of oxide which is deposited around the assay is then moistened with solution of cobalt and treated with the oxidizing flame. Zinc oxide takes a fine yellowish-green and tin oxide a bluish-green color [No. 22 and No. 23].

55. Besides the compounds above mentioned, there are some others which, when exposed to the action of cobalt solution and heat, experience a change of color.

These bodies are either of very rare occurrence, or the change produced in them is not sufficient to be of much importance. In fact, only a few colorations are of much use in the determination of substances—those of alumina, magnesia, zinc, and tin.

The following table gives the more definite colorations:

Blue:	*Alumina;* deep color, infusible.
	Silica and *silicates;* faint color; with much solution of cobalt, black. Fine splinters fuse to a reddish-blue bead.
	Phosphates, *silicates*, and *borates* of the alkalies give a blue glass.
Violet:	*Zirconia;* dirty-violet.
	Magnesium arsenate and *phosphate* fuse and become violet-red.
Flesh-red:	*Magnesia;* pale flesh-red or pink.
	Tantalum pentoxide; hot, light gray; *cold,* flesh-red.
Brown:	*Baryta; hot,* reddish-brown or brick-red; *cold,* colorless.
Green:	*Zinc oxide*, *Titanium dioxide*; yellowish-green.
	Tin oxide; bluish-green.
	Antimony oxide; dirty-green.
Gray:	*Strontia;* dark-gray to black.
	Lime; gray.
	Glucina; bluish-gray.
	Niobium pentoxide; brownish-gray.

EXAMINATION IN THE PLATINUM-POINTED PINCERS FOR FLAME-COLORATION.

56. This experiment serves a double purpose. It acquaints us with the degree of fusibility of the assay and shows the presence or absence of such substances as possess the property of imparting to the flame a peculiar color. Many metals, the sulphides and some other compounds, act upon metallic platinum at a high temperature; the fusibility, etc. of such substances ought to be tested on charcoal. Others, again, fuse so easily that they cannot be held a sufficiently long time between the pincers to observe the color which they impart to the flame; they are most conveniently attached to the hook of the platinum wire, which is best done by heating the wire to redness and then touching the powder of the assay with it; a sufficient quantity generally remains adhering to the wire.

Some minerals decrepitate violently as soon as they are touched with the flame; in such cases Berzelius advises to powder the substance very finely in an agate mortar with addition of a little water, to place one or two drops of the mixture on a piece of charcoal, and to gently heat it by means of the blowpipe flame until the mass lies loosely upon the charcoal; it may then be taken up and held by the pincers. The same process is advantageously employed with substances which fuse only at a very high temperature. In all other cases the substance is roughly powdered and a thin piece which shows prominent edges selected for the experiment.

The chlorides usually give the most intense color, as in the case of copper, strontium, etc., for which reason it is often advisable to moisten the substance with hydro-

chloric acid, or sometimes with sulphuric, as in the case of borates and phosphates.

The substance is exposed to the action of the inner cone of the blowpipe flame, or what is much more convenient, the non-luminous flame of a Bunsen burner provided with a chimney. The colors are best seen against a dark background and when there is not too much light.

If two or more elements which give color are present a mixed color may be produced, or one element may overpower the other; for example, sodium with potassium. In this case the indigo prism, colored glasses, or still better, the spectroscope, must be made use of. (See pages 119, 120, 162.)

The colored flames given by the elements in a pure state may be arranged as follows:

57. Yellow. *Sodium* and its salts cause an enlargement of the outer flame and impart at the same time an intense reddish-yellow color [No. 35]. The presence of other substances which also possess the property of coloring the flame, but not in so high a degree, does not prevent the reaction. Silicates containing sodium exhibit the same phenomenon to a smaller or greater extent, according to their degree of fusibility and the amount of sodium which they contain [No. 59]. With many sodium salts which do not exhibit the reaction very distinctly it can be produced by mixing the salt with some silver chloride to a paste (see par. 5), fastening it to the hook of a thin *iron* wire, and then exposing it to the action of the inner flame.

58. Violet. *Potassium* and most of its salts, with the exception of borate and phosphate, impart to the outer flame a distinct violet color [No. 38]. Also the salts of *rubidium* and *cæsium* and the compounds of *indium*, but

these are rare as compared with the potassium. The presence of a sodium salt prevents the potassium reaction, in which case the flame is viewed through blue cobalt glass or a solution of indigo. Lithium also destroys the potassium flame, unless in very minute quantities. Potassium silicates must be free from sodium and lithium and easily fusible, at least on the edges.

59. Red. *Lithium* and its salts impart to the outer flame a fine *carmine-red* color [No. 60]; lithium chloride shows the reaction better than any other salt. The presence of a potassium salt does not prevent the reaction; the presence of even a small quantity of a sodium salt changes the color to yellowish-red, and a larger quantity prevents the reaction entirely.

Strontium chloride and some other strontium salts, for example, the carbonate and the sulphate, color the outer flame, immediately or after a while, *scarlet-red* [No. 54]. The presence of considerable barium prevents the reaction. Strontium carbonate and sulphate show the reaction remarkably well when mixed with silver chloride and heated on iron wire (see par. 5).

Calcium chloride, calcareous spar, many compact limestones, and fluorite, color the outer flame, immediately or after a while, *yellowish-red;* the color is not so intense as that produced by strontium. Gypsum and anhydrite impart at first a pale yellow, afterward a red color of little intensity [No. 52]. Fluorite gives at first a yellowish flame, but afterward an intense yellowish-red.

60. Green. *Barium* and its salts, especially after moistening with hydrochloric acid, color the outer flame *yellowish-green.* Silicates do not show the reaction. The presence of lime does not prevent the reaction [No. 55].

Copper oxide and some copper salts, as the carbo-

nate and nitrate, impart to the outer flame a fine *emerald-green* color; after moistening with hydrochloric acid, blue. Compounds of iodine and copper and some silicates containing copper, as dioptase and chrysocolla, act in the same manner [No. 70]. *Thallium* and its salts color the flame grass-green.

Phosphoric acid, phosphates, and minerals containing phosphoric acid, especially if moistened with sulphuric acid, impart to the outer flame a bluish-green color, which is only seen for an instant [No. 34].

Boric acid colors the outer flame yellowish-green (green-finch color); if a small quantity of sodium is present the color is mixed with yellow. Minerals containing boric acid should be pulverized and moistened with sulphuric acid.

Molybdenum oxides and molybdenite color the outer flame *yellowish-green,* in which the yellow is stronger than with barium [No. 30].

Tellurium dioxide fuses, emits white fumes, and colors the outer flame green.

Calcium gives a *whitish-green* color, intensely bright.

Ammonium salts often show a *dark-green* flame, which, however, is very weak.

Nitric acid, bronze-green, quickly disappearing.

61. Blue. *Arsenic,* arsenic trioxide, and some arsenides, for example, smaltite and niccolite [No. 79], when heated on charcoal, impart a light-blue color to the outer flame. Some arsenates, for example, scorodite and erythrite, exhibit the same phenomenon in the forceps.

Antimony, fused on charcoal in reducing flame, is surrounded by a feeble greenish-blue flame [No. 1].

Lead, fused on charcoal in reducing flame, is surrounded by an azure-blue flame. Many salts of lead, heated in

the forceps or on platinum wire, impart an intense azure-blue color to the outer flame [No. 3].

Copper chloride colors the outer flame intensely *azure-blue;* after a while the color becomes green, owing to the formation of copper oxide [No. 47].

Copper bromide colors the outer flame greenish-blue; after a while the color changes to green.

Selenium, fused on charcoal in reducing flame, vaporizes with corn-flower-blue flame, with odor of rotten horse-radish.

Indium colors both flames indigo-blue.

CHAPTER III.

SPECIAL REACTIONS FOR THE DETECTION OF CERTAIN SUBSTANCES WHEN IN COMBINATION WITH OTHERS.

62. The preceding chapter and accompanying tables show the changes which many of the simple chemical compounds undergo when heated or when treated with the usual blowpipe reagents. The reactions are sufficiently characteristic to distinguish the various compounds from each other, so that when any one of the above-named substances in a pure state is under examination, there is no difficulty in determining its nature. This, however, is not of frequent occurrence, and in the majority of cases the body to be tested will be of a more complex nature. The results of the experiments will vary accordingly. For instance, a cobalt ore, containing iron, will not impart to the bead of borax or salt of phosphorus in the oxidizing flame a blue color, but a green one, resulting from the mixture of the blue of cobalt and the yellow of iron; lead, when accompanied by antimony, deposits a dark-yellow coating on charcoal resembling that of bismuth, etc. In such cases we may often, by attentively observing all the phenomena which present themselves, and by carefully comparing the results obtained by the various experiments, detect many, if not all, of the components of the substance under examination. Sometimes we attain this end more readily

by varying the order, or by introducing auxiliary agents into the series of experiments; and in other cases again it is only to be arrived at by subjecting the assay to treatments different from those mentioned in the preceding pages.

This chapter contains the principal reactions for the detection of substances which require the application of peculiar agents, and the methods for ascertaining the presence of certain bodies when in combination with others. The substances are arranged alphabetically.

63. Ammonia. Small quantities of ammonia are best detected by mixing the powdered assay [No. 37] with some sodium carbonate or potassium hydrate, introducing the mixture into a glass tube sealed at one end, and applying heat. The escaping gas is characterized by its odor and by its action on reddened litmus paper. White clouds are formed if a glass rod moistened with hydrochloric acid is held before the end of the open tube. From the appearance of this reaction we are, however, not authorized to infer the pre-existence of ammonia in the assay, since from organic matter containing nitrogen, when subjected to this treatment, ammonia is evolved as a product of decomposition.

Antimony. The reactions of antimony and its compounds, see pars. 11, 16, 25, 47, 55, 61, 153, Table II., 1.

64. Haamel's method for distinguishing antimony and other volatile metals, consists in moistening the metal or its oxide coating on coal with hydriodic acid, this reagent being made by passing sulphuretted hydrogen through water containing iodine until the solution becomes clear. On being heated the antimony coating thus formed is intense red, the cadmium white, the lead yellowish-green, and the bismuth brownish-red. In this way one metal

may be detected in the presence of another, the color of the iodides formed being so different and so intense.

Another method for the detection of antimony in presence of *lead* or *bismuth* may be used. The metallic compound [No. 10 or No. 82] is treated with fused boric acid on charcoal, the flame being so directed that the glass is always kept covered with the blue cone, the metallic globule being on the side; by this means the metals become oxidized, lead and bismuth oxides are absorbed by the boric acid, and the antimony oxide will form a ring on the charcoal, provided the temperature is not raised too high.

65. When combined with metals from which it is not easily separated, for example, *copper*, the evaporation of the antimony takes place so slowly that no distinct coating is produced. In this case the assay [No. 83] is treated with salt of phosphorus on charcoal in the oxidizing flame until the antimony, or at least part of it, has become oxidized and entered into the flux. The glass is now removed from the metallic globule and treated on another place of the charcoal with metallic tin in the reducing flame; the presence of antimony will cause the glass to turn gray or black on cooling (Table II., 1). Bismuth behaving under these circumstances in precisely the same manner, the presence of this metal makes the reaction not decisive for antimony. The wet method has then to be resorted to. (See par. 74.)

66. When the *antimony oxides* are accompanied by metallic oxides which, when reduced on charcoal, fuse with the metallic antimony to an alloy, as is the case with the *tin* and *copper* oxides, the latter cannot be recognized by a simple reduction. The oxides have to be treated with a mixture of soda and borax on charcoal in the reducing

flame. The little metallic globules are separated from the flux and fused with from three to five times their own volume of pure lead and some fused boric acid in the reducing flame, care being taken to play with the flame only on the glass. Antimony oxide is volatilized, depositing the characteristic ring, while the oxides of the other metals are absorbed by the boric acid.

67. The *antimony sulphides*, when heated in the open glass tube, show the reaction mentioned in par. 16. When accompanied by *lead sulphide* [No. 18], only a small part of the antimony is converted into oxide, which sublimes; the remainder is changed into a white powder consisting of a mixture of antimony tetroxide, lead sulphate, and lead antimonate. For the detection of antimony proceed as in par. 74. When a compound containing *lead* or *bismuth sulphide*, besides *antimony sulphide*, is heated on charcoal in the reducing flame, a coating is deposited consisting of antimony tetroxide mixed with lead or bismuth sulphate, and, nearer to the assay, a yellow one of lead or bismuth oxide. In such a case the presence of antimony may be ascertained according to par. 101.

68. To detect a small amount of *antimony sulphide* in *arsenic sulphide*, Plattner recommends the following method: the assay [No. 17] is introduced into a glass tube sealed at one end and gently heated; the arsenic sulphide is volatilized and the greater part of the antimony sulphide remains as a black powder in the lower end of the tube; this end is cut off and the black substance taken out and transferred to a tube open at both ends. By applying heat the characteristic antimony reaction will appear.

Arsenic. The reactions of arsenic and its compounds, see pars. 11, 15, 22, 33, 47, 154, Table II., 2.

69. All metallic arsenides yield, when heated in the open glass tube, a sublimate of arsenic trioxide (par. 15), and most of them evolve a garlic odor (par. 22) when heated on charcoal in the reducing flame [No. 74]. Vogel recommends making the substance into a paste with charcoal powder and a dilute solution of shellac in alcohol. If this is made into small pencils and burnt, the odor is given off. Some metals, for example, nickel and cobalt, have a great affinity for arsenic, so that when only a small quantity of the latter is present, the characteristic odor is not observable; in such cases it is sometimes produced when the metallic compound is fused on charcoal with some pure lead in the oxidizing flame.

70. The *arsenic sulphides*, heated in the open glass tube, evolve sulphur dioxide and yield a sublimate of arsenic trioxide. To show in a very decisive manner the presence of arsenic in any of its combinations with sulphur, the powdered assay [No. 77] is mixed with six parts of a mixture of equal parts of potassium cyanide and sodium carbonate, the mass introduced into a tube sealed at one end, and heat applied, at first very gently, but gradually raised to redness. A ring of metallic arsenic will be deposited in the colder part of the tube. (Fig. 31.)

Fig. 31.

71. When *arsenic sulphides* are heated on charcoal, the whole of the arsenic, especially when only small quantities are present, may pass off in combination with sulphur; but when such compounds [No. 17] are mixed with from three to four parts of neutral potassium ox-

alate or potassium cyanide and exposed to the reducing flame, potassium sulphide is formed and the arsenic escapes with its peculiar odor, if not combined with cobalt or nickel.

72. To detect a very small quantity of *arsenic trioxide*, the following method may be used: a glass tube is closed by drawing it out to a point; the assay [No. 48] is introduced into the point and a charcoal splinter placed just above it; the tube is then heated to redness at the place where the charcoal splinter lies, and as soon as this is incandescent, heat is also applied to the assay. (Fig. 32.) If any moisture given off from the substance when

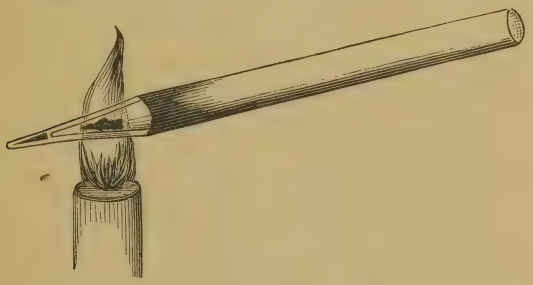

Fig. 32.

heated condenses upon the tube, it should be removed by means of a roll of filter-paper. The arsenic trioxide is volatilized, and its vapors, while passing over the red-hot charcoal, become reduced and deposit a black metallic ring of arsenic in the colder part of the tube. By cutting the tube below the ring and heating this part by the flame of a gas-lamp, the arsenic is volatilized, thereby emitting its characteristic odor.

73. To show the presence of arsenic in *arsenites* and *arsenates*, it will in most cases be sufficient to mix the

substance [No. 48] with sodium carbonate and heat it on charcoal in the reducing flame. Sometimes it is necessary to treat the assay with a mixture of sodium carbonate and potassium cyanide in the manner mentioned (par. 70); and in other cases again, where but small quantities of arsenic trioxide or arsenic pentoxide are combined with metallic oxides which are readily reduced, recourse must be had to the humid way.

Bismuth. The reactions of bismuth and its compounds, see pars. 12, 17, 22, 26, 47, 155, Table II., 3.

74. Bismuth is usually detected by its coating. If in combination with sulphur and heated alone on charcoal, the yellow coating is surrounded by a white coating of bismuth sulphate. Heated with sodium carbonate, the sulphate is not formed. Bismuth, when alloyed with other metals, or when as sulphide in combination with other sulphides, is in many cases, and most especially so when accompanied by lead or antimony, not to be detected with certainty by the coating which it deposits on charcoal. In such a case the assay [No. 11] is treated on charcoal until a copious yellow coating is formed. The coating is carefully scraped off from the charcoal and dissolved in salt of phosphorus on platinum wire with the oxidizing flame. The colorless bead is removed from the wire, placed on charcoal, a little metallic tin added, and the whole exposed to the reducing flame. If bismuth was present, the glass assumes, on cooling, a dark-gray or black color. The antimony oxide showing the same behavior, the assay, if not quite free from antimony, has to be treated on charcoal in the oxidizing flame until the whole of it has been volatilized, and the remaining mass treated on another piece of charcoal as above mentioned.

According to Von Kobell, any compound of bismuth treated before the blowpipe with a mixture of equal parts of potassium iodide and sulphur on a large coal, gives a beautiful and very characteristic red coating, at quite a distance from the assay. In case of sulphide the sulphur is not necessary. If lead is present a deep-yellow coating is formed, which, however, does not interfere with the bismuth lying nearer the assay.

Cornwall* suggests the following method to detect bismuth in presence of lead and antimony: to the mixture of the three oxides an equal volume of sulphur is added, and the whole treated before the blowpipe in a deep cavity on coal with the blue flame for a short time. The resulting fused sulphides are removed to a flat coal and treated alternately with the oxidizing flame and reducing flame until antimony fumes have nearly ceased and an impure blue-lead flame appears. The residue is powdered and an equal part of a mixture of one part of potassium iodide and five of sulphur, by weight, added. This is then heated in an open tube, 10 to 12 cm. long and not less than 10 mm. wide, over a Bunsen gas-burner or spirit-lamp. A distinct red bismuth iodide sublimate is formed, about 10 mm. above the yellow sublimate of lead iodide.

Care must be taken not to confound with the bismuth sublimate, a sublimate of iodine, which may condense on the upper part of the tube, but at a greater distance from the assay.

75. Boric Acid. With many borates, which do not impart to the outer flame the peculiar yellowish-green color (par. 60), this reaction may be produced by reducing the substance [No. 33] to powder, adding a drop

* "American Chemist," March, 1872.

of concentrated sulphuric acid, fastening the mixture into the hook of the platinum wire, and playing on it with the blue cone of the flame (see par. 60).

76. Another way, and by which even a very small quantity of boric acid in salts and minerals may be detected, is: to reduce the substance to a very fine powder, to mix it with from three to four parts of a mixture of four parts of acid potassium sulphate and one part of fluorite, perfectly free from boric acid, and to knead the whole with a little water into a thick paste. This mass is then fastened to a platinum wire and exposed to the blue cone of the flame. While the mass enters into fusion boron fluoride is formed, which, on escaping, colors the flame intensely yellowish-green. The reaction appearing sometimes only for a few seconds, and the coloration being only momentary, the flame should be very carefully observed.

The method proposed by Iles is extremely reliable. The substance, finely powdered, is placed on platinum foil, moistened with sulphuric acid, the excess of acid volatilized by heat, and the powder then made into a paste with glycerine. If this is taken up by a platinum wire and placed in the flame, the latter is colored yellowish-green.

77. If borates of the alkalies or alkaline earths are dissolved in dilute hydrochloric acid, and one end of a piece of turmeric paper dipped into the solution, after drying at 100° C., this end of the paper will become *brownish-red.* Hydrochloric acid alone, if too strong, will produce a *dark-brown* on turmeric paper. The reddish color of the paper, if moistened with an alkali, is changed to black.

78. **Bromine.** Bromides treated with salt of phosphorus and copper oxide on platinum wire, or treated with cop-

per sulphate on silver foil, show the same reaction as chlorides (par. 83), with this difference, that the blue color of the outer flame is rather greenish, especially on the edges [No. 39]. When the bromine is all driven off, the green flame of the copper alone remains.

79. To discriminate bromides from chlorides more distinctly, the bromide is fused with acid potassium sulphate, both in the anhydrous state, in a small matrass with long neck. Sulphur dioxide is evolved and the matrass is filled with yellow vapors of bromine, characterized by their peculiar odor. The color of the gas is only clearly seen by daylight. Silver bromide may be distinguished from silver chloride by the asparagus-green color which it assumes when exposed to the sunlight after fusion with acid potassium sulphate.

80. Goldschmidt, for the detection of a bromine compound alone, or in presence of iodine and chlorine, gives the following method: If a bromine compound is fused in an open glass tube with pulverized bismuth sulphide, made by fusing metallic bismuth with sulphur, a yellow sublimate is formed. An iodine compound treated in the same manner forms a red sublimate, and a chlorine compound a white one. With a little care these elements can be readily recognized in presence of one another.

The presence of iodine, on account of its violet vapors, often renders the bromine reaction somewhat uncertain.

Cadmium. The reactions of cadmium and its compounds, see pars. 12, 35, 47, 159, and Table II., 4.

81. To detect a very small quantity of cadmium, 1 per cent. or less, in *zinc* or its *ores*, the pulverized assay is mixed with soda and exposed for a short time to the reducing flame on charcoal. A distinct coating of brown cadmium oxide is deposited. The zinc, being less vol-

atile, forms a coating only with continued blowing [No. 16].

82. Chlorine. Some copper oxide is dissolved by means of the oxidizing flame in a bead of sodium phosphate on platinum wire until the glass is nearly opaque, some grains of the pulverized assay [No. 41] are then made to adhere to the bead, and both heated with the tip of the blue cone of the flame. If chlorine is present the flame now assumes an intense azure-blue color, owing to the formation of copper chloride (par. 61). This test is very delicate and will show the presence of a very minute quantity of chlorine. Bromine produces a similar but somewhat greenish (par. 78) flame (pars. 10, 48).

When a chloride is heated with dry potassium chromate and concentrated sulphuric acid, dark, brownish-red vapors of chloro-chromic acid are evolved, which condense to drops of the same color. With ammonium hydrate this liquid becomes yellow.

83. Another method is to place on silver-foil some ferrous sulphate or some copper sulphate, to moisten it with a drop of water, and then to add the assay [No. 41]. After a while the silver will be found blackened. Substances which are insoluble in water have previously to be fused with a little soda on platinum wire, to form a soluble chloride.

84. Chromium. Chromium oxide gives very characteristic reactions with the fluxes on platinum wire (see Table II., 6), but when accompanied by a large quantity of iron, copper, or other substances which also intensely color the borax and salt of phosphorus beads, the chromium color frequently becomes very indistinct.

85. In such a case, and when the chromium is not in combination with silica, its presence may be detected in

the following manner: the assay-piece [No. 68] is reduced to a fine powder and mixed with about twice its own volume of a mixture of equal parts of soda and nitre. The mass is fastened into the hook of a thick platinum wire, or placed into a small platinum spoon, and treated with a powerful oxidizing flame. An alkaline chromate is formed which is dissolved in water, the solution supersaturated with acetic acid, boiled, and a crystal of lead acetate added. If chromium was present, a yellow precipitate of lead chromate will appear. The precipitate may be collected on a filter and tested in the borax and salt of phosphorus beads, when the characteristic chromium-reactions will be produced. If instead of lead acetate, silver nitrate is added, a dark, purplish-red precipitate of silver chromate is formed.

Silicates which contain only a little chromium, but much iron or other coloring oxides of metals, are not decomposed by nitre. In this case a pulverized mineral is fused on coal in the oxidizing flame with one part of sodium carbonate and one-half to three-fourths parts of borax to a clear bead; this is pulverized and evaporated to dryness with hydrochloric acid. The chlorides thus formed are dissolved in water, the silica filtered off, the iron is oxidized by boiling with a few drops of nitric acid, and the bases, sesquioxides of chromium, iron, etc., precipitated by ammonia from the acid solution. The precipitate is collected on a filter, washed, and fused with soda and nitre as above. By this means alkaline chromates are formed, which can be decomposed by acetic acid and lead acetate, as already described.

Cobalt. The reactions of cobalt, see Table II., 7.

86. To detect cobalt when in combination with other metals, see pars. 47, 99, *c*, 164.

To show its presence in *arsenides*, the assay [No. 75] is placed on charcoal and heated until fumes of arsenic trioxide are no longer emitted. (Lead and bismuth, if present, form the characteristic coatings.) Borax is now added and the heat continued until the glass appears colored. If the color is not pure blue, the presence of iron is indicated. The glass is in this case removed from the globule, and the latter treated repeatedly with fresh quantities of borax until the pure cobalt-color is obtained. Nickel and copper, if present, do not enter into the flux before the whole of the cobalt is oxidized. If we wish to ascertain the presence of these metals, the glass which is colored by cobalt is removed from the globule, and the latter treated with fresh portions of borax in the oxidizing flame until the color of the bead becomes brown, indicative of nickel. The glass is again removed and the globule treated with salt of phosphorus in the oxidizing flame; when copper is present the bead assumes a green color, which remains unaltered on cooling. Treated with tin on charcoal, the glass turns opaque and red from the reduction to cuprous oxide.

87. To detect *cobalt* in *sulphides*, the assay [No. 76] is heated on charcoal in the reducing flame until all volatile substances are driven off, the remaining mass reduced to powder, well calcined, and the calcined mass treated with borax on charcoal in the oxidizing flame. If cobalt is the only coloring metal present, the bead will exhibit a pure blue color; a small addition of iron will make the glass appear green while hot, but blue when cold. Copper and nickel, when present to some extent, will prevent the cobalt-color being distinctly seen. The bead is in this case exposed to the reducing flame until it appears transparent and flows quietly; the oxides of

copper and nickel are by this means reduced, and the pure color of cobalt, or that of cobalt mixed with iron, becomes apparent. The separation of the metals may be promoted by adding a little pure lead, and the substance freed from an excess by treating it alone on coal, after which it is fused in the oxidizing flame with salt of phosphorus to detect nickel and copper.

Copper. The reactions of copper and its compounds, see pars. 47, 60, 61, 172, and Table II., 8.

88. The red color which copper imparts to the borax or salt of phosphorus bead, when heated on charcoal in the reducing flame in contact with tin (see Table II., 8), is very characteristic, and will in most cases clearly show the presence of this metal; but if only a small quantity of copper is associated *with other metals*, the reaction is not easily obtained; in this case we may proceed as follows:

The assay [No. 18, or No. 83, or No. 82] is placed on charcoal and played upon with the oxidizing flame until antimony and other volatile metals are driven off. Some vitrified boric acid is fused on charcoal to a glassy globule, the assay placed close to it, and the whole covered with a large reducing flame. When the metallic globule begins to assume a bright metallic surface, the flame is gradually converted into a sharply-pointed blue cone, which is made to act only on the glass, leaving the metallic globule untouched, and so situated that it touches the glass on one side, and on the other side is in close contact with the charcoal. During this process lead, iron, cobalt, part of the nickel, and such of the more volatile metals as were not entirely removed by the previous calcination, as bismuth, antimony, zinc, etc., become oxidized, and their oxides partly volatilized and partly absorbed by

the boric acid. The remaining metallic globule is then removed from the flux and treated on charcoal with salt of phosphorus in the oxidizing flame, when the copper is oxidized and dissolved. The limpid bead is then refused in the reducing flame with addition of tin. A trace of copper may thus be made to produce distinctly the characteristic reaction, rendering the cold bead distinctly red and wholly or partially opaque.

89. To show the presence of copper in compounds which contain much *nickel*, *cobalt*, *iron*, and *arsenic*, the assay [No. 79] is first treated with borax on charcoal in the reducing flame, when the greater part of iron and cobalt are dissolved. The remaining globule is then mixed with some pure lead and treated as shown in par. 88. Arsenic is for the most part driven off, and the rest of the iron and cobalt, with some nickel, absorbed by the boric acid. The globule is removed from the glass and treated with salt of phosphorus in the oxidizing flame; dark-green while hot, and somewhat lighter green when cold (produced by the mixture of the yellow of nickel and the blue of copper), indicates the presence of copper.

To detect copper when in combination with tin, see par. 124.

90. To detect copper in *sulphides*, the pulverized assay [No. 73] is calcined and the calcined mass treated as above, or, when the amount of copper is not very small, simply treated with borax or salt of phosphorus on charcoal in the oxidizing flame, and subsequently with addition of tin in the reducing flame. The presence of copper is then shown by the red color and the opaqueness of the glass on cooling. This reaction is only prevented, or at least made indistinct, by antimony or bismuth, which cause the glass to turn gray or black. In this case the

assay is, after calcination, mixed with soda, borax, and some pure lead, and the mixture fused on charcoal in the reducing flame. The metallic globule is then heated on charcoal to drive off the antimony, and afterwards treated with boric acid as above.

91. When a mineral which contains copper is heated in the blue cone, the outer cone of the flame frequently assumes a green, or, if the metal is in combination with chlorine, an azure-blue, color. This reaction, if not produced by heating the substance alone, may sometimes be obtained by adding a drop of concentrated hydrochloric acid to the pulverized assay [No. 70], evaporating to dryness, mixing the dry powder with a little water to a stiff paste, fastening this into the hook of a platinum wire, and then exposing it to the blue cone of the flame.

92. Fluorine. To detect fluorine in those minerals where it occurs only as an accessory element in combination with weak bases, and which at the same time contain water, as in No. 57, a small piece is placed in a glass tube sealed at one end, a wet Brazil-wood paper introduced into the open end, and heat applied. Hydrofluoric acid is evolved, which turns the red color of the test-paper to straw-yellow and corrodes the glass. Mica, containing not more than ¾ per cent. of fluorine, shows the reaction very distinctly.

If the mixture is heated from above downward, it is not so likely to be thrown out from the tube. The etching of the tube is best seen after the tube is cleaned and dried.

93. Another process, and by which the presence of fluorine in all kinds of compounds may be shown, is to mix the pulverized assay with some salt of phosphorus which has previously been fused on charcoal and then reduced

to powder; to place the mixture on platinum-foil, which is connected with an open glass tube in such a manner as to constitute a kind of tubular continuation to the former, and to heat with the blowpipe flame until the mass enters into fusion. If the flame is so directed that the products of decomposition are made to pass through the glass tube, and a moistened Brazil-wood paper is introduced into the other end, the presence of hydrofluoric acid is indicated by the change of color which the latter experiences, and often by its pungent odor. In some cases the glass will also be dulled or a deposit of silica be formed. This test is very delicate.

94. Gold. (See pars. 30, 47, 170, and Table II., 10.) When gold is in combination with metals which are volatile at a high temperature—ex. gr. tellurium, mercury, antimony—it is only necessary to heat the alloy on charcoal with the oxidizing flame, when the gold remains behind in a pure state, and may be recognized by its physical properties. Lead is removed by the process of cupellation, as explained in par. 117.

95. When associated with copper, the presence of which is easily detected by salt of phosphorus on charcoal, the alloy—for example, gold coin—is dissolved in pure melted lead and the new compound subjected to the process of cupellation on bone-ash. Copper is by this means entirely removed. To test the remaining globule for silver, it is treated with salt of phosphorus on charcoal in the oxidizing flame; the silver is gradually oxidized and dissolved by the glass, which when cold assumes an opal-like appearance. To determine approximately the relative proportions of the two metals, the metallic globule is taken from the cupel, placed in a small porcelain dish containing some nitric acid, and heat applied. If the alloy con-

tains 25 per cent. of gold or less, it turns black, the silver is gradually dissolved, and the gold remains behind as a brown or black spongy or pulverulent mass. If the alloy contains more than 25 per cent. of gold, the globule turns also black, but the silver is not dissolved. If both metals are present in about equal proportions, the globule remains unaltered. If the amount of gold is considerable, it is indicated by the color of the alloy.

In both of the latter cases it must be fused on coal with borax and at least twice its weight of silver, free from gold, and then treated with nitric acid, when the separation will be complete. To form a gold button, it must be well washed with distilled water and fused on coal with borax, and it will then have the pure gold color and bright surface.

96. When associated with metals which alone are infusible before the blowpipe—as ex. gr. platinum, iridium, palladium—the metallic globule obtained by cupellation shows much less fusibility than pure gold. The exact nature of the foreign metals cannot be ascertained before the blowpipe; the humid way must be resorted to.

97. Iodine. Iodides, tested with a salt of phosphorus bead which is saturated with copper oxide, as shown in par. 82, impart to the outer flame a fine green color [No. 40].

Fused with acid potassium sulphate in a glass tube closed at one end, violet vapors are evolved, iodine sublimes, and sulphur dioxide is given off.

Iodides mixed with about one-third of their weight of copper sulphate and heated in a glass tube are decomposed, as shown by the violet vapors, which color paper, moistened with starch, blue.

98. Iodine, in combination with silver or with alkalies, can be detected in the presence of other halogens by mix-

ing the powdered substance with bismuth sulphide (prepared by heating bismuth and sulphur together) and heating on charcoal before the blowpipe flame. A red coating of bismuth iodide is formed if iodine is present.

Iron. The reactions of the oxides of iron, see Table II., 13. Also pars. 12, 47, 162.

99. *a.* To distinguish protoxide from peroxide, the substance is added to a borax bead containing copper. With peroxide the bead is colored bluish-green, whilst with protoxide red lines or flakes of cuprous oxide appear.

b. To detect iron along with *easily-fusible metals*, such as lead, bismuth, antimony, tin, or zinc, the substance is heated on charcoal with borax in the reducing flame. The easily-reducible metals do not become oxidized, and consequently are not absorbed by the glass. The glass is separated from the metallic bead, and is heated on a fresh piece of charcoal in the reducing flame, when it acquires the characteristic bottle-green color produced by iron, and becomes vitriol-green on addition of tin.

c. In presence of *cobalt* the bead is not green, but blue in color. In such case iron is sought for by heating the blue glass on platinum wire in the oxidizing flame sufficiently long to convert all the iron into peroxide. With very little iron present, the bead is green when hot, and blue when cold; with more iron, the bead is dark-green when hot, and pure green when cold, this latter resulting from a mixture of the yellow iron and blue cobalt colors. The residual metal on the charcoal after the treatment with borax (often only nickel and copper) is examined according to par. 88.

d. An admixture of *manganese* colors the bead in the oxidizing flame blood-red. By reduction with tin on charcoal the bead becomes vitriol-green. If *cobalt* be

present along with *manganese*, a dark-violet bead is produced in the oxidizing flame, which in the reducing flame becomes green when hot and blue on cooling.

e. To test for iron in *nickeliferous* substances, the assay is dissolved in borax in the oxidizing flame and then heated on charcoal in the reducing flame. Metallic nickel separates out, and the iron, remaining dissolved in the glass, colors it green.

f. A substance containing *iron* and *copper* gives a green borax bead in the oxidizing flame both before and after cooling; from this bead copper separates on charcoal under the reducing flame, and the glass becomes green from iron. If the amount of copper present be small, the assay is fused together with borax, sodium carbonate, and assay-lead, the metallic bead obtained heated with boric acid in the oxidizing flame, and the copper sought for by the aid of salt of phosphorus and tin.

g. If *iron* and *chromium* occur together, the color of the glass affords no indication of the presence of iron. The substance is fused with sodium carbonate on charcoal in the reducing flame, the reduced iron is separated from the slag by washing, and the latter is fused with potassium nitrate for the detection of chromium.

h. *Iron* and *uranium oxides* cannot be distinguished from one another in the dry way. To separate them, the assay is fused with acid potassium sulphate, extracted with water, and the solution treated with ammonium carbonate to precipitate the iron; the filtrate is acidified, boiled to expel carbon dioxide, and the yellow uranium precipitated by ammonia. Both products are then further examined.

i. A substance containing *iron*, *nickel*, *cobalt*, *manganese*, and *copper* is fused with metallic arsenic or with

potassium arsenate, and the mass is treated with borax in successive portions in the oxidizing flame.

There results—

First, a yellowish-green color from iron.
Then a blue " " cobalt.
" a brown " " nickel.
" a green " " copper.

Under the reducing flame nickel and copper can be separated from the borax glass, whilst iron, cobalt, and manganese remain dissolved, and are looked for according to par. 99, *d*.

Lead. The reactions of lead and its compounds, see pars. 12, 27, 61, 158, and Table II., 15.

100. An alloy of lead and zinc [No. 12] deposits a coating of lead oxide mixed with zinc oxide; the presence of lead is shown by the color of the coating and by the azure-blue tinge which it imparts to the reducing flame (see par. 27). Test the zinc coating with cobalt solution, which turns it yellowish-green when heated.

An alloy of lead and bismuth [No. 11] deposits a coating somewhat darker than that of pure lead, in which the presence of bismuth may be detected as shown in par. 74, and the presence of lead by the azure-blue color of the reducing flame.

101. To detect lead in sulphides, the substance is placed on charcoal and treated with the reducing flame; the lead is detected by its coating. An admixture of antimony cannot by this means be ascertained, since the ring of lead sulphate surrounding that of the oxide bears a striking resemblance to the coating formed by antimony oxide. In this case the pulverized assay [No. 82] is mixed with a sufficient quantity of soda and treated for

a short time with the reducing flame. If no antimony is present a pure yellow coating with bluish-white edges is formed; but in presence of antimony this coating is surrounded by another white one of antimony oxide. The lead oxide coating appears, moreover, darker than usual, resembling that of bismuth, owing probably to the formation of lead antimonate. A very small quantity of antimony by this method cannot be found out with certainty, since, by keeping up the blast for some time, the sodium sulphide begins to vaporize and to coat the charcoal with a ring of sodium sulphate (see par. 38).

102. When lead sulphide is associated with a considerable quantity of copper sulphide [No. 18], the metallic globule obtained by the process of reduction does not betray, by its physical properties, the presence of lead. But if the alloy is removed from the flux and played upon with a powerful oxidizing flame, the greater part of the lead will be volatilized and deposit a coating.

Lead chloride before the blowpipe first fuses and then gives two coats—one of the chloride, white and volatile, and another of the oxide, less volatile. It also imparts a blue color to the reducing flame.

Lead phosphate alone on coal fuses to a globule, and affords no coat or a very slight one. Crystallizes on cooling.

103. Lithium. To detect lithium in silicates which contain only little of it, proceed as follows: The substance [No. 64] is reduced to a fine powder and mixed with about two parts of a mixture of one part of fluorite with one and a half parts of acid potassium sulphate; a few drops of water are added and the whole kneaded into a paste. The mass is fused with the blue cone of the flame into the hook of a platinum wire. If lithia is present the outer flame will appear red. If only a small amount is

present the color is not very intense, and verges into violet. The presence of potassium does not prevent the reaction, but makes the flame appear still more violet; sodium makes the reaction uncertain.

If boric acid be present in the silicate, as in tourmaline, the outer flame at first exhibits a green tinge, but afterward a wine or less intense red from the lithia.

In presence of phosphoric acid —as in case of tryphylite, for example — it causes a green flame, perceptible along with the red one, especially after moistening with sulphuric acid.

Another method of detecting lithium when mixed with sodium is to dip the assay, moistened with hydrochloric acid, into melted wax, and then heat it in the blue flame, by which the red color is produced immediately.

Manganese. The reactions of manganese, see Table II., 16. Also pars. 47, 181.

104. If a bead containing manganese, just taken from the oxidizing flame, be brought into contact with a crystal of potassium nitrate or chlorate, or be thrown into a porcelain capsule containing the powdered reagent, a violet frothy mass of potassium permanganate is formed.

The presence of manganese in any compound substance is readily detected by mixing the pulverized assay [No. 63 or No. 81] with about two parts of soda and one of nitre, and fusing it by means of the oxidizing flame on platinum foil. Potassium manganate is formed, which, while hot, is green and transparent, and on cooling turns bluish-green and opaque. The slightest trace may be detected in this way. Chromium does not prevent the reaction, merely changing the color to yellowish-green. It is only in presence of silica and cobalt that this test is not available, since at a high temperature the silica unites with the

soda to form sodium silicate, which, in dissolving the cobalt oxide, produces a blue glass, and thus interferes with the manganese color. In this case the silica must first be separated in the wet way.

Metallic compounds containing manganese should be dissolved in nitric acid, the solution evaporated to dryness, and the ignited residue tested with sodium carbonate and potassium nitrate, as above.

Mercury. The reactions of mercury and its compounds, see pars. 10, 11, 18, 47, 156, and Table II., 17.

105. Mercury is detected in amalgams [No. 9] by the sublimate of metallic mercury which they yield when heated in a glass tube closed at one end. The globules if small are best seen with a small magnifying-glass.

When in combination with sulphur [No. 78], chlorine [No. 49], iodine, or oxygen-acids, the substance is previously mixed with some anhydrous soda or some neutral potassium oxalate. The acids, etc. are retained by the soda, and mercury sublimes.

If the quantity of mercury is so small that the nature of the sublimate cannot with certainty be ascertained, the experiment has to be repeated, a piece of iron wire around which a gold-leaf has been wrapped being at the same time introduced into the tube and held close above the assay. The gold-leaf will turn white, even when the amount of mercury present is very small.

Molybdenum. For the reactions of molybdenum and its compounds, see pars. 38, 51, 60, and Table II., 18.

106. Small quantities of molybdic acid may be detected by adding a little of the powdered substance to some strong sulphuric acid on a piece of platinum bent up at the sides. After heating till evaporation begins and then cooling, the foil is repeatedly breathed upon. Where only blue spots

occur on cooling, if breathed upon an intense blue color is produced. Or if a little alcohol be added to the blue spots instead of breathing upon them, and then burnt off, the color is produced (see par. 174).

Nickel. The reactions of nickel, see Table II., 19.

107. Fusible metallic compounds of nickel are treated with borax on charcoal in the reducing flame; iron, cobalt, etc. enter into the flux and may be detected as shown in par. 86, while the metals the oxides of which are easily reduced remain behind. This operation is repeated until the glass appears no longer colored. The remaining globule is treated with salt of phosphorus in the oxidizing flame. We now obtain either the pure color of nickel or that of nickel mixed with copper, yellowish-green (see par. 89); in this case it is treated on charcoal with tin, whereby the presence of copper may be ascertained, the bead becoming opaque and red. Bismuth or antimony prevents the reaction for copper, the bead turning black instead of red. Such compounds must, previous to their treatment with fluxes, be heated on charcoal in the reducing flame until all volatile substances are driven off [No. 79].

In arsenides and sulphides, nickel is detected by the methods given for cobalt under the same circumstances (see par. 87).

Small quantities of nickel in the presence of cobalt may be detected by treating a small quantity of the substance with borax on platinum wire; a dark-colored bead is formed, which is placed on charcoal with a small gold bead and fused in the reducing flame. When cold, the gold bead is separated from the slag by a slight blow with a hammer, and is fused with salt of phosphorus in the oxidizing flame. The glass takes up the easily-soluble

cobalt oxide, becoming blue; and fresh quantities must be added until the color changes to green, and finally becomes yellow. The gold may afterward be refined by cupelling with lead on bone-ash (see par. 163).

108. Nitric acid. The perfectly dry substance [No. 43] is heated in a matrass with some acid potassium sulphate; orange-yellow vapors of nitrogen tetroxide are emitted, even if but a small quantity of a nitrate is present. Or if chlorine is present the substance should be heated with litharge free from lead peroxide, which at first absorbs the nitric acid, but yields it up at a higher temperature. A piece of paper moistened with a solution of ferrous sulphate, free from peroxide and acidulated with sulphuric acid, is inserted into the neck of the tube, which should be rather long, and nitrogen tetroxide if present will color the paper yellowish to brown (see par. 60).

109. Phosphoric acid. A very minute quantity of phosphoric acid may be detected by pulverizing the substance [No. 65], adding a drop of concentrated sulphuric acid, fastening the paste into the hook of a platinum wire, and playing upon it with the blue cone of the flame; the outer flame will assume a bluish-green color (see par. 60).

Certain nitrogen compounds, as nitric acid, ammonium nitrate, ammonium chloride, etc., when fastened into the hook of a platinum wire and touched with the cone of the blue flame, impart to the outer flame a bluish-green color resembling that caused by phosphoric acid (see par. 60).

110. For very small quantities of phosphoric acid Bunsen has proposed a test which consists in mixing the substance with two or three times as much soda, and placing the completely dried mixture in the drawn-out part of a small tube, similar to those used in testing for arsenic. The mixture is again heated to remove all moisture, a

long bit of sodium, or, better, magnesium wire, inserted into it, and fused with the blowpipe. When cold, the portion of the tube containing the fused mass is broken off, placed in a porcelain dish, and wet with a few drops of water; if phosphoric acid was present, the phosphuretted hydrogen formed may be recognized by its odor.

111. Potassium. The violet color of the flame is sufficiently characteristic for potassium (see par. 41). But being altogether prevented, or at least made very indistinct, by the addition of a few per cent. of soda or lithia, it can only in a very few cases be made use of. For the detection of potassium in silicates it is almost entirely unavailable, because these compounds almost always contain some soda.

112. If the base of a compound consists essentially of potassium, the following method may be advantageously employed for its detection: Some borax, to which a little boric acid has been added, is melted into the hook of a platinum wire, and so much pure protoxide of nickel, free from cobalt, added that the glass on cooling shows a distinct brownish color. A small piece of the substance under examination [No. 38] is made to adhere to the glass, and the whole fused together with the oxidizing flame. If the assay-piece contained no potassium, the color of the glass, after perfect cooling, will have remained unchanged; but if potassium was present in sufficient quantity, the glass will appear bluish.

The simplest means of detecting potassium in a salt in which, owing to a greater or less amount of soda, the violet coloration of the flame cannot be recognized, consists in viewing the color of the flame through deep-blue cobalt glass or a stratum of indigo solution (see page 119). The presence of potassium is recognized, according to the thickness of the intervening medium, by the violet

or poppy-red color, while a very large amount of soda produces a blue color, and a smaller quantity is not perceptible.

The carbon of organic matter produces the same color as potassium, and if contained in the assay should be removed by ignition.

If lithium is present, a thicker stratum of solution or darker glass must be used.

According to Merz, a green glass may be used in some cases with advantage, the lithium flame being invisible through it, while the potassium and barium flames appear bluish-green, and that of sodium orange-yellow.

In testing silicates with the cobalt glass, they should first be heated with pure gypsum in the flame, thus forming sulphate of the alkali, which is volatile, and imparts to the flame its characteristic color.

113. Selenium. The reactions of selenium are very characteristic. In non-volatile compounds, which do not give the red sublimate mentioned in par. 11, γ, the selenium is detected by heating a small piece of the substance [No. 84] on charcoal in the oxidizing flame, when the peculiar odor is evolved; if much selenium is present, a coating is deposited (see par. 36). Selenites and selenates are treated on charcoal with soda in the reducing flame, when a reduction takes place and the selenium vaporizes with the characteristic odor (see pars. 20, 61, 152).

114. Silica. Pure silica [No. 51], when treated with borax on platinum wire, dissolves slowly to a transparent glass which fuses with difficulty. Treated with salt of phosphorus in the same manner, only a small quantity is dissolved, the rest floating in the liquid bead as a semi-transparent mass. The behavior with soda, see par. 45. With a little cobalt solution it assumes a pale-bluish

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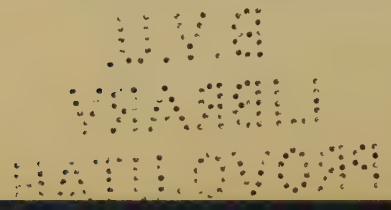
color, which, on addition of a large quantity of the reagent, turns dark-gray or black; very thin splinters may be fused by a great heat to a reddish-blue glass.

115. Silicates [No. 58], when treated with salt of phosphorus on platinum wire, are decomposed; the bases unite with the free phosphoric acid to a transparent glass, in which the silica may be seen floating as a gelatinous, cloudy mass. The bead ought to be carefully observed while hot, since many silicates form a glass which on cooling opalizes or becomes opaque, when, of course, the phenomenon can no longer be seen. The experiment is best performed with a small splinter of the substance under examination, and only when this does not appear to be affected by the flux, the finely-pulverized substance should be used. If but a very small quantity of silica is present, the glass will appear perfectly transparent. Its presence in this case cannot be detected by means of the blowpipe.

116. Silicates containing at least so much silica that the quantity of oxygen in the acid is twice that of the oxygen in the base, dissolve, when treated with soda on charcoal, with effervescence, to a transparent glass, which remains when cold. When less silica is present decomposition also takes place, but the glass turns opaque on cooling, the amount of sodium silicate which is formed not being sufficient to dissolve the eliminated bases.

Silver. The reactions of silver, pars. 29, 171, and Table II., 27.

117. When in combination with metals which are volatile at a high temperature—for example, bismuth, lead, zinc, antimony—the substance is heated alone on charcoal, when, after volatilization of these metals by long blowing, a button of pure silver remains behind, and a reddish coating is deposited on the charcoal. If associated



with much lead or bismuth, these metals are best removed by cupellation, a process which is performed in the following manner: Finely-pulverized bone-ash is mixed with a minute quantity of soda, and made with a little water into a stiff paste; a hole is now bored into the charcoal, filled with the paste, and its surface smoothed and made slightly concave by pressing on it with the pestle of the little agate mortar. The mass is then dried by the flame of a gas or spirit lamp. On this little cupel the assay [No. 13] is placed, and heated with the oxidizing flame until the whole of the lead or bismuth is oxidized and absorbed by the cupel. The silver, or if gold is present the alloy of silver and gold, remains as a bright metallic button on the cupel.

118. When combined with metals which are not volatile, but which are more easily oxidized than silver, the presence of this metal may in some cases be detected by simply treating the alloy with borax or salt of phosphorus on charcoal. Copper, nickel, cobalt, etc. are oxidized, and their oxides dissolved by the flux, while silver remains behind with a bright metallic surface. But when these metals are present to a considerable extent, another course has to be pursued—a course which may always be taken when a substance is to be assayed for silver or silver and gold.

119. The assay-piece [No. 83] is reduced to a fine powder, mixed with fused borax and metallic lead (the quantities of which altogether depend upon the nature of the substance, and for which, therefore, no general rule can be given), and the mass placed in a cylindrical hole of the charcoal. A powerful reducing flame is given until the metals have united to a button, and the slag appears free from metallic globules. The flame is now con-

verted into an oxidizing flame and directed principally upon the button. Sulphur, arsenic, antimony, and other very volatile substances are volatilized; iron, tin, cobalt, and a little copper and nickel become oxidized and are absorbed by the flux; silver and gold and the greater part of the copper and nickel remain with the lead (and bismuth, if present). When all volatile substances are driven off, the lead begins to become oxidized and the button assumes a rotary motion; at this period the blast is discontinued, the assay is allowed to cool, and when perfectly cold the lead button is separated from the glass by some slight strokes with a hammer. It is now placed on a cupel of bone-ash and treated with the oxidizing flame until it again assumes a rotatory motion. If much copper or nickel is present, the globule becomes covered with a thick infusible crust, which prevents the oxidation; in this case another small piece of pure lead has to be added. The blast is kept up until the whole of the lead and other foreign metals—viz. copper and nickel—are oxidized; this is indicated by the cessation of the rotatory movement, if only little silver is present, or by the appearance of all the tints of the rainbow over the whole surface of the button if the ore was very rich in silver; after a few moments it takes the look of pure silver. The oxides of lead, copper, etc. are absorbed by the bone-ash, and pure silver, or an alloy of silver with other noble metals, remains behind; the button may be tested for gold, etc. after the method given in par. 95.

The silver chloride can be reduced on coal with soda.

120. Sulphur. The presence of sulphur in sulphides may in many cases be detected by heating in a glass tube (see pars. 10, 14), or on charcoal with the oxidizing flame.

In testing for sulphur, an alcohol or other flame free from sulphur compounds, and not coal gas, should be used (see pars. 49, 185).

121. A very delicate test for the presence of sulphur, in whatever combination it may be contained in the substance, and which possesses, moreover, the advantage over all other methods of being very easily performed, is to mix the pulverized assay [No. 36] with some pure soda, or, better still, with a mixture of two parts of soda, perfectly free from sulphates, and one of borax, and to treat it on charcoal with the reducing flame. The fused mass is removed from the charcoal, powdered, the powder placed on a silver foil or a bright silver coin, and a drop of water added. If the substance under examination contained any sulphur, a black spot will be formed on the silver foil, owing to the formation of silver sulphide from the decomposition of the sodium sulphide, which in its turn resulted from the decomposition of the sulphide or sulphate, or other sulphur compound of the assay-piece, under the influence of soda, charcoal, and a high temperature. Selenium and tellurium show the same reaction. The former is readily recognized by the peculiar odor which it emits when heated on charcoal alone, and the latter by its coating and flame.

If a substance containing sulphur is fused with sodium carbonate in the reducing flame, moistened with water in a watch-glass, and a little sodium nitro-prusside added, a fine reddish-purple color is produced.

A dilute solution of ammonium molybdate with an excess of hydrochloric acid is colored fine blue by a small quantity of sulphuretted hydrogen or sulphides dissolved in water.

Sulphides treated with hydrochloric acid liberate sul-

phuretted hydrogen, which may be recognized by its odor and blackening a piece of paper moistened with lead acetate.

To decide whether the reactions obtained in the experiments above were owing to the presence of a *sulphide* or to that of a *sulphate*, the finely-pulverized substance [No. 76] is fused in a small platinum spoon with some potassium hydrate. The spoon with the contents is then placed in a vessel containing some water, and a piece of silver foil placed in the liquid. If the silver remains perfectly bright, a sulphate was present; if it turns black, a sulphide. The absence of substances which might exercise a reducing influence is required.

122. Tellurium. The presence of tellurium in mineral substances is detected by the tests given in par. 11, 37, 151. In presence of *lead* or *bismuth* the reactions in the open tubes and on charcoal are not quite sure. In this case we may subject the assay to the following treatment: The substance is mixed with some soda and charcoal-powder, the mixture introduced into a glass tube closed at one end and heated to fusion; after cooling, a few drops of hot water are poured into the tube; if tellurium was present, sodium telluride has been formed, which dissolves in hot water with a purplish-red color. This test is applicable to show the presence of tellurium in a great many compounds, even when it occurs in the oxidized state.

Natural tellurium compounds, when gently heated in a matrass with an excess of sulphuric acid, impart to it a purple or hyacinth-red color, which disappears on adding water, while a blackish-gray precipitate is formed. When a mineral containing tellurium is treated on coal it generally yields a white tellurium dioxide coat, with a reddish-

yellow border, which disappears under the reducing flame, imparting to the flame a green, or, in presence of selenium, a bluish-green, tinge. The horse-radish odor would be a certain indication of selenium.

If the mineral contains *lead* or *bismuth*, and is treated alone on coal for only a few moments, no pure tellurium dioxide coat is obtained, but a mixture of this with lead or bismuth oxide is liable to be deposited. This difficulty can be remedied by mixing the powdered assay with an equal volume of vitrified boric acid and treating it in the reducing flame. The lead or bismuth oxide is dissolved in the boric acid, notwithstanding the reducing flame, and yields no coat, while the tellurium alone volatilizes and coats the coal. When much selenium is also present a portion of it is deposited on the coal, and then the tellurium dioxide coat is less distinct. In such cases the mineral must also be tested in the open tube.

Tin. The reactions of tin and its compounds, see pars. 12, 28, 55, 173, and Table II., 30.

123. The presence of tin is indicated by its coating when the substance [No. 7], alone or mixed with soda, is exposed to the reducing flame on charcoal.

If a small quantity of a tin compound be added to a borax bead colored blue by copper oxide, and the reducing flame be applied, the bead becomes brown.

If substances containing tin oxide are heated on charcoal with soda and borax in the reducing flame, malleable beads of tin are obtained. These are separated from the slag and heated in the oxidizing flame, which converts them into white oxide, and is deposited on the charcoal near the assay. Treated with cobalt solution, the coating becomes bluish-green. When occurring together with zinc it can only be detected with certainty in the wet way.

124. To detect *copper in tin or its alloy*—as bronze, bell-metal, and gun-metal—the assay [No. 15] is fused with a flux consisting of one part of soda, one-half part of fused borax, and one-third part of silica. The flame is so directed that the metallic globule assumes a rotatory motion. When in this state the glass is kept covered as much as possible with the oxidizing flame, care being taken that the globule is at one side in contact with the glass, and at the other with the charcoal. The tin becomes oxidized, and the oxide, in a measure as it is formed, absorbed by the flux, whilst the copper remains behind. The latter is separated from the glass and further treated with salt of phosphorus, whilst the slag is powdered and reduced on charcoal with sodium or potassium carbonate.

Tin, when present in alloys, is almost always detected on fusing them upon coal; the globule is crusted with oxide, which can be removed with some difficulty after adding borax.

Sulphides containing tin, but forming no coat of oxide of tin near the assay, when treated alone on coal, must be roasted and treated in the reducing flame with soda and borax, when metallic tin is obtained, which may be tested alone on coal. If other reducible metals are present they form an alloy, in which the other metals can be recognized by means of the fluxes.

Titanium. The reactions of titanium are given in pars. 45, 51, 55, 176, and Table II., 31.

125. Titanium dioxide, when forming the principal constituent of any mineral substance, is easily detected by its behavior with the fluxes, but when in combination with bases these reactions are not always clearly perceptible, being frequently obscured by the predominating reaction

of the base. In such cases we may subject the assay to the following treatment, by which even very small quantities of titanium dioxide will become apparent: The substance [No. 62] is reduced to a very fine powder, mixed with from six to eight parts of acid potassium sulphate, and fused in a platinum spoon at a low red heat; the fused mass is dissolved in a porcelain vessel in the smallest possible quantity of water, aided by heat. If concentrated, it may be heated to boiling. There remains an insoluble residue, which is allowed to settle; the clear liquid is poured off into a larger vessel, mixed with a few drops of nitric acid and at least six volumes of water, and heated to ebullition. If the substance under examination contained any titanium, a white precipitate of metatitanic hydrate forms on boiling. If the solution is not acidified with nitric acid before boiling, a yellow, ferruginous precipitate is obtained when the substance contains iron. The precipitate is collected on a filter, washed with water, acidulated with nitric acid, and tested with salt of phosphorus, either on platinum wire or on coal. If the amount of metatitanic hydrate is so small that it does not give in the reducing flame to the salt of phosphorus the violet color of titanium dioxide, it is only necessary to add a little iron sesquioxide when the assay is upon a wire, or a small piece of iron wire when on coal, and to fuse the glass for a short time with the reducing flame; it appears yellowish while hot, and brownish-red when cool.

If titanium dioxide be fused with caustic potash, dissolved in water, and the solution evaporated after addition of an excess of hydrochloric acid and a piece of tin-foil, the liquid becomes violet-colored, and, on dilution with water, rose-red.

Tungsten. The reactions are given in pars. 45, 51, 175, and Table II., 32.

126. Tungsten may be detected by fusing the assay with five times its weight of sodium carbonate, the mass extracted with water, and the tungstic acid precipitated with hydrochloric acid in the form of a white powder. The precipitate becomes yellow on boiling, and is insoluble in excess of the acid (distinction from molybdic acid), but dissolves in ammonium hydrate. The solution, after acidification, gives a deep-brown coloration with potassium ferrocyanide, and after some time a precipitate of the same color separates; with silver nitrate a white, and with stannous chloride a yellow, precipitate is produced. On acidifying with hydrochloric acid and warming, the precipitate changes to a clear blue color, which is very characteristic.

127. Uranium. The presence of this metal is easily recognized, in substances which contain no other coloring constituents, by the reactions given in Table II., 33; the most characteristic test is that with salt of phosphorus. In presence of much *iron* this reaction becomes indistinct; we may then operate in the following manner: The finely-pulverized substance [No. 67] is fused with acid potassium sulphate, the fused mass dissolved in water, mixed with ammonium carbonate in excess, the liquid separated from the precipitate by filtration, and the filtrate heated to ebullition. If any uranium was present, a yellow precipitate is thrown down, which gives with the fluxes the reactions of pure uranium.

If the substance contains *copper* oxide, it is treated with soda, borax, and a silver bead on coal in the reducing flame until all the copper is reduced and taken up by the silver, after which the slag, containing uranium and other

non-reducible oxides, like iron in a low state of oxidation, is dissolved by warming it with a little nitric acid, treated with excess of ammonium carbonate, and the process conducted as above (see par. 182).

Vanadium. For the reactions of vanadium and its compounds, see pars. 41, 51, 180, and Table II., 34.

128. On fusing vanadium compounds with soda and nitre on a platinum spiral, extracting with water, adding acetic acid in excess, and then silver nitrate, a yellow precipitate is formed. By evaporating the fused mass with aqua regia, a yellow or brownish solution is formed, which turns blue on the addition of stannous chloride.

If the solution of the fused mass in water is acidified and well shaken with hydrogen peroxide, it becomes red, and retains this color on the addition of ether, the latter remaining uncolored.

Zinc. The reactions for zinc and its compounds, see pars. 12, 34, 54, and Table II., 35. Also par. 160.

129. A small amount of zinc, when associated with considerable quantities of lead, or bismuth, or antimony, or tin, cannot always with certainty be ascertained by means of the blowpipe.

If the substance under examination contains the zinc as oxide [No. 22], or but a small quantity of sulphide, it is mixed with soda and treated on charcoal in the reducing flame. Substances consisting essentially of zinc sulphide may be thus treated without the addition of soda, and such as contain, besides zinc oxide, other metallic oxides, are conveniently mixed with some soda to which about one-half of its weight of borax has been added. A ring of zinc oxide is deposited on the charcoal. When lead is present [No. 12] the coating is frequently not pure, being mixed with the coating of lead.

In this case it is moistened with some cobalt solution and heated again with the oxidizing flame; the lead oxide is reduced by the red-hot charcoal and volatilized, while the zinc oxide remains behind with a green color (see par. 56). It is well to moisten the charcoal at the point where the coating is to be formed with the cobalt solution.

The above reaction is not affected by the presence of lead and bismuth, but in the presence of much antimony a little zinc can only be found with difficulty before the blowpipe, for the oxides of antimony formed will have a green color, and cannot be driven off with the oxidizing flame. In many compounds, however, all of the antimony may be volatilized with the oxidizing flame, and the zinc then treated with the cobalt solution.

If tin is present the zinc cannot be recognized by the coating on coal, as its oxide assumes a bluish-green color with the cobalt solution.

When zinc occurs in small quantity it may be determined by using as a flux a mixture of nitre, sodium chloride, and soda, a coating being formed more readily from the volatile chlorides.

130. CONDENSED VIEW OF BLOWPIPE REACTIONS.

Arranged according to the phenomena observed.

Experiment.	Observation and Inference.

(1.) In Glass Matrass, or tube closed at one end.	*Water is given off:* water of crystallization; alkaline reaction = NH_3; acid reaction = volatile acids.
	Gas is evolved: O, SO_2, H_2S, NO_2, CO_2, CO, CN, NH_3, HF, I, Br.
	Sublimate is formed: white = NH_4Cl, Hg_2Cl_2, $HgCl_2$, Sb_2O_3, As_2O_3, TeO_2;
	grayish-black = As, Hg, Te;
	colored: *hot*, yellowish-brown; *cold*, yellow = S;
	hot, black; *cold*, reddish-brown = antimony sulphide;
	hot, brownish-red; *cold*, reddish-yellow = arsenic sulphide;
	black, on rubbing red = cinnabar;
	reddish-black (dark-red powder) = Se.
	Change of color: white, yellow, white = ZnO;
	white, yellow, brown, light-yellow = SnO_2;
	white, brownish-red, yellow = PbO;
	white, orange, pale-yellow, Bi_2O_3;
	red, black, red (volatile) = HgO;
	red, black, red (non-volatile) = Fe_2O_3.
	Substance melts: alkaline salts.
	Carbonization takes place: organic bodies.
	Substance becomes phosphorescent: alkaline earths, earths, ZnO, SnO_2.
	On heating with sodium carbonate, ammonia is evolved: ammoniacal salts and organic nitrogen compounds.

BLOWPIPE REACTIONS.—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.

(2.) In the Open Tube.	*Odor emitted:* of SO_2 = sulphur and sulphides;
	of rotten horse-radish = selenium and selenides (steel-gray sublimate with red border).
	Sublimate is formed: white and crystalline = As;
	metallic globules = Hg;
	white fumes, sublimate partially volatile = Sb;
	white fumes, sublimate fusible to colorless drops = Te.

(3.) Alone on Charcoal, or Aluminium-foil.	*Substance is fusible:* (*a*) non-metallic bodies = alkaline and some alkaline-earthy salts;
	(*b*) metals: readily fusible = Sb, Pb, Cd, Te, Bi, Zn, Sn;
	difficultly fusible = Cu, Au, Ag.
	Substance is infusible: (*a*) non-metallic bodies = salts of the earths and alkaline earths, SiO_2;
	(*b*) metals = Fe, Co, Ni, Mo, Pt, Ir, Rh, Os, W.
	Substance detonates: nitrates, chlorates, bromates, and iodates.
	Substance intumesces: substances containing water, borates, alum.
	Odor emitted: S, As, Se, Te.
	Flame-coloration: yellow = Na;
	yellowish-red = Ca;
	red = Li, Sr;
	green = Ba, B_2O_3, P_2O_5, MoO_3, Cu;
	blue = $CuCl_2$, Se, As, Pb;
	violet = K.

Blowpipe Reactions.—*Continued.*

Experiment.	Observation and Inference.

(3.) Alone on Charcoal, or Aluminium-foil. (*Continued.*)	*Metal-reduction and coating:*
	
	(1.) *Metal reduced without coating.*
	
	Shining bead = Ag, Au, Cu;
	Gray powder = Fe, Co, Ni, Mo, W, Pt, Pd.
	
	(2.) *Metal reduced with coating.*
	
	coating, bluish-white and volatile = Sb;
	" *hot*, orange; *cold*, lemon-yellow = Bi;
	" *hot*, lemon-yellow; *cold*, sulphur-yellow = Pb;
	" *hot*, yellowish; *cold*, white = Sn;
	" dark-red = Ag.
	
	(3.) *Coating without reduced metal.*
	
	coating, white and volatile = As;
	" *hot*, yellow; *cold*, white = Zn;
	" reddish-brown, with variegated border = Cd;
	" steel gray = Se;
	" white with red border = Te;
	" *hot*, yellow; *cold*, white; by blowing upon, first blue, then dark-red = Mo. (In oxidizing flame only.)

Blowpipe Reactions.—*Continued.*

Experiment.	Observation and Inference.				
	Color of Bead.	*Oxidizing Flame.*		*Reducing Flame.*	
		Hot.	Cold.	Hot.	Cold.
(4.) On Platinum Wire with Borax.	Yellow (non-saturated bead).	Fe, U, Ce, Cr, Mo.....	.....	Ti, Mo.....	Ti.
	Yellow (saturated bead).....	V, Ti, W, Pb, Bi, Sb, Zn, Cd.....	Fe, U, Ce.....	W.	
	Red (non-saturated bead)....	.....	.....	.....	Cu (brownish).
	Red (saturated bead).....	Fe, Ce, U, Cr, Mo.....	.....	.....	Cu (brownish).
	Brown.....	.....	Ni.....	(s. b.), Mo, V, Ti.....	(s. b.), W, Mo, Ti.
	Violet.....	Mn, Ni.....	Mn.		
	Blue.....	Co.....	Co, Cu.....	Co	Co.
	Green.....	Cu.....	Cr, V.....	Fe, U, Cr.....	Fe, V, U, Cr.

BLOWPIPE REACTIONS.—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.				
	Color of Bead.	*Oxidizing Flame.*		*Reducing Flame.*	
		Hot.	Cold.	Hot.	Cold.
(5.) On Platinum Wire with Salt of Phosphorus.	Yellow (non-saturated bead).	Fe, U, V, Ce, Ag.....	V, Ni.....	Ti, Fe.....	Ni.
	Yellow (saturated bead).....	U, V, W, Ti, Ag, Pb, Bi, Sb, Zn, Cd..	V, Ni.....	Ti.....	Ni.
	Red (non-saturated bead)...	Ni, Cr.....	.....	Cr.....	Cu.
	Red (saturated bead).....	Fe, Ce, Ni, Cr..	Fe (brownish).	Fe, Cr, Ni...	Cu.
	Brown.....	.....	.....	V.	
	Violet.....	Mn.....	Mn.....	.....	Ti.
	Blue.....	Co.....	Co, Cu.....	Co.....	Co, W.
	Green.....	Cu, Mo.....	U, Cr, Mo.....	U, Cu, Mo, W.....	U, Mo, Cr, V.
	Silica Skeleton = SiO_2.				

BLOWPIPE REACTIONS.—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.
(6.) On Charcoal with Sodium Carbonate.	*Sodium sulphide formed:* sulphates and sulphides. *Metal-reduction and coating*, as in No. 3.
(7.) On Platinum-foil with Sodium Carbonate and Nitre.	Yellow mass = Cr. Green " = Mn.
(8.) On Charcoal with Cobalt Solution.	Blue infusible mass = Al_2O_3, SiO_2, and earthy phosphates and silicates. Blue glass = alkaline phosphates, borates, and silicates. Green mass = ZnO, TiO_2, SnO_2, Sb_2O_3. Flesh-colored mass = MgO. Brown mass = BaO. Gray mass = BeO, CaO, SrO. Violet mass = ZrO_2.
(9.) With $Na_2S_2O_3$ in a tube closed at one end.	White = ZnO. Brown = SnO_2. Black = PbO, Fe_2O_3, CoO, Red = Sb_2O_3. Green = Cr_2O_3, MnO. CuO, NiO, UO_3, Bi_2O_3, Yellow = As_2O_3, CdO. Ag_2O, HgO.
(10.) With H_2SO_4, or $HKSO_4$ in Glass Matrass.	*Colored vapors:* brown = N_2O_4; yellowish-green = Cl_2O_4; violet = I; reddish-brown = Br. *Odorous gases:* SO_2, HCl, HF, H_2S. *Colorless and inodorous gases:* CO_2, CO.

BLOWPIPE REACTIONS.—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.
(11.) With Zn and HCl after previous decomposition.	Solution is colored blue, green, blackish-brown = MoO_3. blue, copper-red = WO_3. blue, green, violet = V_2O_5. green = CrO_3. violet = TiO_2.
(12.) Heated on Platinum Wire, after Moistening with HCl.	*The flame is colored:* Yellow = Na; through blue glass invisible to blue; through green glass, orange. Yellowish-red = Ca; reaction obscured by Ba; through blue glass, greenish-gray; green glass, siskin-green. Red = Li; obscured by Na; through blue glass, violet; green glass, invisible. Red = Sr; obscured by Ba; through blue glass, violet-red; green glass, momentarily yellowish. Green = B_2O_3, P_2O_5, Ba (through green glass, bluish-green), MoO_3, Tl. Blue = Cu (subsequently green), In, Se, As, Pb, Sb. Violet = K; obscured by Na; through blue glass, purple-red; green glass, bluish-green.

CHAPTER IV.

COLORED FLAMES, FLAME REACTIONS, AND SPECTRUM ANALYSIS.

MANY substances, when brought into a colorless or non-luminous flame, color it in a remarkable manner. The colorations are, in many cases, characteristic of the elements yielding them, and furnish excellent means of detecting the latter, even in the minutest quantities, with great ease and certainty. Thus sodium-salts tinge the flame yellow; potassium compounds, violet; lithium-salts, carmine-red; and on account of this peculiarity they may be distinguished from each other by the simplest experiments.

The Bunsen lamp, with chimney, previously described (Fig. 4), is especially adapted to such observations. The substance to be tested is brought by means of the platinum wire-loop (Fig. 12) into the zone of fusion of the gas-flame. The alkalies and alkaline earths are most remarkable in their coloring effects on the flame. If we compare together various salts of the same base, we find that they all, if volatile at the temperature of the flame, give the same color, but the color differs in intensity, being strongest with the most volatile salts, and *vice versâ*. Thus, potassium chloride gives a deeper tinge to the flame than potassium carbonate, and carbonate a stronger than potassium silicate. Sometimes a non-volatile compound is made to exhibit a characteristic tint by

the addition of some flux or decomposing agent. Silicates which contain but a few *per cent.* of potassium, and of themselves do not color the flame, give a coloration after heating with some pure calcium sulphate, which decomposes them, producing calcium silicate and volatile potassium sulphate.

In mixtures of several substances which may be individually detected without difficulty when they exist separately, it usually happens that a mixed and indecisive coloration is produced, or one substance masks all the others. Thus, in a mixture of sodium- and potassium-salts only a sodium flame, in one of barium- and strontium-salts only a barium flame, is evident to the unassisted eye. We have learned two methods of dissecting these mixed flames so as to recognize their component colors with surprising facility and distinctness.

The first method, introduced into chemistry by Cartmell, and further developed by Bunsen and Merz, consists in observing the colored flames through colored media (stained glass, indigo solution, etc.). These act by extinguishing the color of one metal, and thus developing that of the other. A mixture of sodium and potassium, which to the eye has a pure yellow flame, when seen through a deep-blue cobalt glass or a solution of indigo exhibits the violet tint of potassium, without any traces of the yellow sodium flame. Cartmell detected lithium in the presence of sodium and potassium by comparing the mixed color of the flames of those bases with that of the flame of pure potassium when both are viewed through an indigo solution. Bunsen found that the discrimination of these bases in presence of each other is more easily effected by observing the *succession of changes of color* which the mixed flame produced by

these substances experiences when the rays reach the eye after passing through gradually thicker layers of an indigo solution.

131. The apparatus for these observations is simple, viz.:

1. A hollow prism, made of plate glass (Figs. 23, 24), whose principal section forms a triangle, with two sides of 150 millimètres and one of 35 millimètres long. The solution with which it is filled is prepared by dissolving 1 part of indigo in 8 parts of fuming oil of vitriol, adding 1500 to 2000 parts of water, and filtering.

In the following experiments the prism is moved horizontally before the eye, so that the rays of the flame always pass through gradually thicker layers of the medium. The alkaline substances, brought singly into the melting-space, exhibit the following changes:

a. Chemically pure **calcium chloride,** $CaCl_2$, produces a yellow flame, which, even with very thin layers of the indigo solution, passes through a tinge of violet into the original blue-lamp flame.

b. Chemically pure **sodium chloride,** NaCl, the same.

c. Chemically pure **potassium carbonate,** K_2CO_3, *or* **potassium chloride,** KCl, appears of a sky-blue, then violet, and at last of an intense crimson-red, even when seen through the thickest layers of solution. Admixtures of sodium or calcium do not hinder the reaction.

d. Chemically pure **lithium carbonate,** Li_2CO_3, *or* **lithium chloride,** LiCl, gives a carmine-red flame, which, with increasing thickness of the medium, becomes gradually feebler, and disappears before the thickest layers pass before the eye. Calcium and sodium are also without influence on this reaction.

2. A blue, a violet, a red, and a green glass. The blue is colored by cobalt protoxide; the violet, by manganese

sesquioxide; the red (partly colored and partly uncolored), by cuprous oxide; and the green, by iron sesquioxide and cupric oxide. The stained glasses found in commerce and employed for ornamenting windows generally possess the requisite shades of color.

Merz, who has made a complete investigation of this subject, employs with these glasses Bunsen's burner, and also a flame of pure hydrogen. The substances which he describes as giving characteristic colors to the flame of Bunsen's burner, in addition to those previously known, are nitric and chromic acids, while phosphoric and sulphuric acids give a peculiar coloration to the dark core of the flame of hydrogen.

132. The flame of Bunsen's burner gives three sorts of color:

a. **Border colors.** These are of course peculiar only to the most volatile substances. To produce them, the loop of platinum wire is to be held outside of the flame about one or two millimètres from the lower portion of the outer limit.

b. **Mantle colors.** Those, namely, which are seen when the substance is held in the bright blue-colored mantle which forms the outer portion of the flame.

c. **Flame colors.** To produce these, the loop is to be held horizontally and in the hottest part of the mantle. The hydrogen flame yields another species of color—viz. the

d. **Core colors.** These are produced only by sulphuric and phosphoric acids, which communicate respectively a blue and green tinge to the cold core of the hydrogen flame.

The following, according to Merz, is a list of the more commonly-occurring substances which color the flame, with the color they impart:

BLUE FLAMES.

(*Consult page* 123.)

Intense blue, afterward green	Copper chloride.
Pale clear blue	Lead.
Light-blue	Arsenic.
Greenish-blue	Antimony.
Blue mixed with green	Copper bromide.
Blue core color	Sulphuric acid.
Indigo-blue	Indium.

GREEN FLAMES.

(*Consult page* 123.)

Bronze-green border color	Nitric and nitrous acids.
" " " "	Ammonium compounds.
" " " "	Cyanogen "
Greenish-blue border color	Hydrochloric acid.
Green mantle color	Boric acid.
Gray yellow-green border color	Phosphoric acid.
Yellowish-green flame color	Barium compounds.
Dark-green	Iron wire.
Full-green	Copper.
Intense emerald-green	" iodide.
Emerald-green, mixed with blue	" bromide.
Pale-green	Phosphoric acid.
Intense whitish-green	Zinc.

RED FLAMES.

(*Consult page* 124.)

Intense-crimson	Strontium compounds.
Reddish-purple	Calcium "
Violet	Potassium "
Dark brownish-red border color and a rose-red mantle color	Chromic acid.

YELLOW FLAMES.

(*Consult page* 125.)

Yellow	Sodium compounds.
Feeble brownish-yellow	Water.

133. Blue flames. **Cupric chloride** gives an azure-blue zone, and **cupric nitrate** a pure green flame color. By the combined observation of both colors, **copper** may be distinguished from all other metals which give similar colors. The other flame-coloring metals—such as **arsenic, antimony, tin, lead, mercury,** and **zinc**—exhibit, especially in the form of chlorides, more or less intense bluish or greenish mantle colors, which, however, cannot be advantageously used as reactions for the metals themselves.

Sulphuric acid produces a beautiful blue core color, being reduced to **sulphur dioxide.** The free acid gives the color when the platinum loop is held in the border of the flame, but a sulphate must be held in the middle of the flame. In the latter case it is well to dip the test into strong **hydrochloric acid** or hydrofluosilicic acid.

134. Green flames. Nitric and nitrous acids give a bronze-green border color, usually with an orange-colored border. The test is to be previously dried in the flame, and dipped into a solution of **acid potassium sulphate,** or into dilute **hydrochloric acid,** according as we wish to test for nitric or nitrous acid. Ammonium and cyanogen compounds give the same bronze-green border, but more faintly. **Hydrochloric acid** gives a very weak greenish-blue border color, which lasts for a very short time, and therefore does not deserve attention. The acid is, however, decomposed, and the **chlorine** may easily be recognized.

Boric acid gives a beautiful green mantle color, which is so intense that the acid may be recognized in the presence of large quantities of phosphoric acid. Borates are to be decomposed with **sulphuric acid.** Phosphoric

acid gives a gray yellow-green border color, as well as a beautiful green core color. The dry test is to be dipped into **sulphuric acid**, and held in the flame in the manner already pointed out, in order to show the border color. The green core color is less sensitive, but indispensable in recognizing phosphoric acid in the presence of large quantities of boric acid, and is produced by alternately moistening the test with a solution of hydrofluosilicic acid, and igniting it in the hydrogen flame, until the color distinctly appears.

Barium may be recognized by the yellowish-green flame color, which appears blue-green through the green glass. If the green disappears, and a red flame color makes its appearance, the test is to be repeatedly moistened with **hydrochloric acid**, and immediately introduced while wet into the hottest part of the flame. When the blue-green color is no longer seen, proceed to examine for **calcium.**

135. **Red flames. Calcium** is present when the red flame color, on evaporating the last portion of **hydrochloric acid**, appears siskin-green through the green glass. **Strontium** gives in this case a weak yellow. **Strontium** may be recognized by the purple or rose color which is seen through the blue glass, when the test, after moistening with **hydrochloric acid**, is evaporated to dryness in the flame.

Potassium gives a gray-blue mantle color and a rose-violet flame color. These colors appear reddish-violet through the blue glass, violet through a violet glass, and blue-green through a green glass. The test is to be moistened with **sulphuric acid**, and repeatedly exposed to the flame for a short time.

Chromic acid gives a dark brownish-red border color

and a rose-red mantle color. The dry test is to be moistened with concentrated **sulphuric acid** and held in the border. Chromic oxide gives no color, and is to be first oxidized to chromic acid by moistening with a solution of sodium hypochlorite and drying.

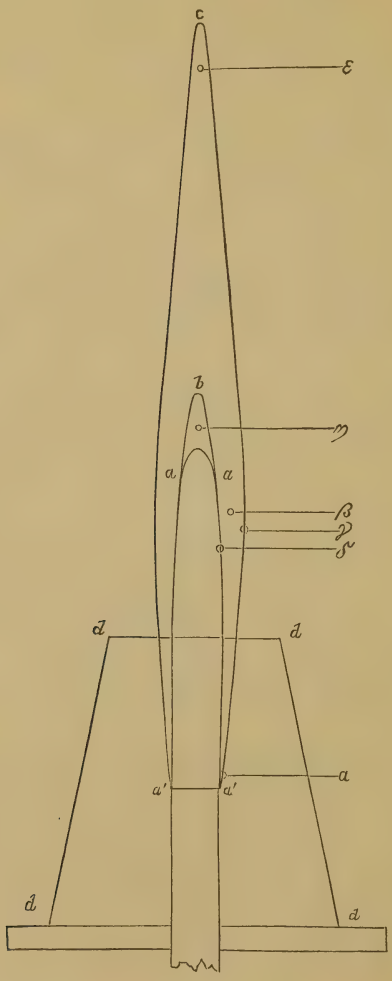
136. Yellow flames. Sodium gives an orange-yellow flame color, which in very large quantity appears blue, but in small quantity is invisible through the blue glass. Through the green glass the flame appears orange-yellow, even with the smallest quantity. This glass is particularly adapted to the recognition of **sodium** in all its compounds. The test should be moistened with **sulphuric acid,** dried, and held in the hottest point of the flame.

BUNSEN'S FLAME REACTIONS.

Almost all the reactions which can be performed by means of the blowpipe may be accomplished with greater ease and precision in the non-luminous flame of the gas-burner. This flame, moreover, possesses several peculiarities which render it available for reactions, by which the smallest traces of many substances occurring mixed together can be detected with certainty when the blowpipe and even still more delicate methods fail. Only the principal reactions that can be obtained in this way are here given.

137. Bunsen's gas-lamp. This lamp, with non-luminous flame, is represented in Fig. 4, and must be made about three times as large as the drawing. It must be furnished with a cap for closing and opening the draught-holes, so as to be able to regulate the supply of air for every dimension of the flame. The conical chimney *d d d d* (Fig. 33) must also be made of such a size that the flame burns perfectly steady. Fig. 33 represents the

Fig. 33.



flame of its proper size. It is composed of the following three chief divisions:

A. **The dark cone,** *a a a a,* containing the cold unburnt gas mixed with about 62 per cent. of air.

B. **The flame mantle,** *a c a b,* formed of the burning coal-gas mixed with air.

C. **The luminous point,** *a b a,* not seen when the lamp is burning with the draught-holes open, but obtained of the size required for the reactions by closing these holes up to a certain point.

The following six points in the flame are used in the reactions:

1. **The base of the flame** lies at α; its temperature is comparatively very low, as here the burning gas is cooled by the upward current of cold air, and much heat is absorbed by the cold end of the metal tube. If mixtures of flame-coloring substances are held in this part of the flame, it is often possible to vaporize the most volatile constituent, and thus in the first few moments to obtain tints which cannot be observed at higher temperatures, because they then become masked by colors produced by the volatilization of the remaining substances.

2. **The zone of fusion** lies at β, somewhat above the first third of the flame in height, and midway between the inner and outer limits of the mantle at the point where the flame is thickest. This is the point in the flame which possesses the highest temperature, and it is therefore used in testing substances as regards their melting-point, their volatility, emissive power, as well as for all processes of fusion at high temperatures.

3. **The lower oxidizing flame** lies at γ, in the outer margin of the zone of fusion, and is especially suitable for the oxidation of substances dissolved in beads of fused salts.

4. The upper oxidizing flame at ε is formed by the highest point of the non-luminous flame, and acts most powerfully when the draught-holes of the lamp are wide open. This flame is suited for the oxidation of larger portions of substance, for roasting off volatile-oxidation products, and generally for all those cases of oxidation in which an excessively high temperature is not needed.

5. The lower reducing flame lies at δ, on the interior edge of the mantle next to the dark central zone. As the reducing gases at this point are mixed with unburnt atmospheric oxygen, many substances remain here unaltered which become deoxidized on exposure to the upper reducing flame. This point of the flame gives, therefore, very valuable reactions which cannot be obtained with the blowpipe. It is especially available for reductions on charcoal and in beads of fused salts.

6. The upper reducing flame is formed by the luminous point η, produced over the dark zone when the admission of air is lessened by the gradual closing of the draught-holes of the lamp. If this luminous point is made too large, it will be found that a test-tube filled with cold water becomes covered with a film of lampblack: this never ought to occur. This flame contains no free oxygen, is rich in finely-divided incandescent carbon, and hence it possesses far more powerful reducing powers than the lower reducing flame. It is especially available for reducing metals when it is desired to collect them in the form of films.

METHOD OF EXAMINATION IN THE VARIOUS PARTS OF THE FLAME.

A. Behavior of the Elements at High Temperatures.

138. This is one of the most important reactions which can be employed for the detection and separation of sub-

stances. The possibility of producing, with the flame of the lamp alone, a temperature as high as or higher than

Fig. 34.

Fig. 35.

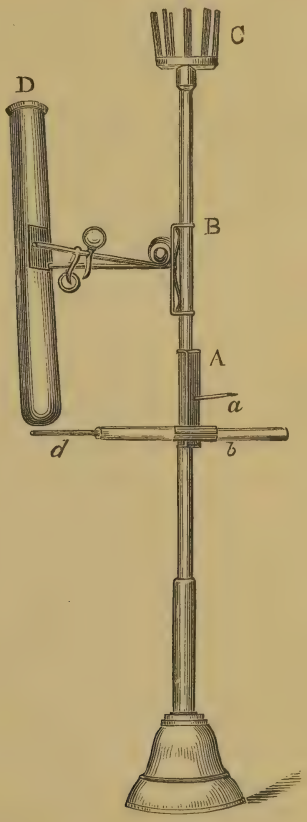


Fig. 36.

that of the blowpipe depends upon the fact that the radiating surface of the heated body be made as small as possible. The arrangement for bringing the substances into

the flame must therefore be on a very small scale. The platinum wire upon which the substance is heated must scarcely exceed the thickness of a horsehair, and one decimètre in length of the wire must not weigh more than 0.034 grm. It is impossible to obtain the results hereafter detailed if a thicker wire than this is employed. Substances which act upon platinum, or which will not adhere to the moistened surface of the metal, are held in the flame upon a thin thread of asbestos, of which a hundred may be obtained from one splinter of the mineral. These threads must not exceed in thickness one-fourth of that of an ordinary lucifer-match. Decrepitating substances are ground to the finest powder on the porcelain lamp-plate with the elastic blade (*a*) of the knife (Fig. 34), and drawn up on to a moistened strip of one square centimètre of filter-paper. If the paper is then burnt, being held with the platinum forceps, or, better, between two rings of fine platinum wire, the sample remains as a coherent crust, which now may without difficulty be heated in the flame.

If the substance require to be heated in the flame for a long period, the holder (Fig. 35) is used. The arm (*a*) is fastened to the carrier (A), so fixed on the stand by a spring (as seen at B) that it can be moved both horizontally and vertically. The glass tube (Fig. 36) is held on this arm (*a*), and the fine platinum wire fused on to the tube thus held in the flame. The splinters of asbestos are stuck into the glass tube (*b*), which slips into the holder, and may then be moved with the carrier (A). The carrier (B) carries a spring-clamp for holding test-tubes which have to be heated for a considerable time in a particular part of the flame. The little turn-table (C) contains nine upright supports to hold the wire tubes (Fig.

36) employed in the experiments. By means of these arrangements a particle of the substance under examination is brought into the flame, and its behavior in the coldest and hottest parts of the flame is ascertained, the substance being examined with a lens after each change of temperature. The following six different temperatures can be obtained in the flame, and these points may be judged of by observing the tints attained by the thin platinum wire:

1. Below a red heat.
2. Commencing red heat.
3. Red heat.
4. Commencing white heat.
5. White heat.
6. Strong white heat.

It is scarcely necessary to remark that these different temperatures must not be ascertained by the glow of the substances themselves, as the luminosity of different bodies depends not only upon the temperature, but also mainly upon their specific power of emission.

The following phenomena are observed when a sample of a substance is heated:

139. Emission of light. The emissive power of substances is ascertained by placing them on the platinum wire in the hottest part of the flame. The sample is of weak emissive power when it is less luminous than the platinum wire; of a mean emissive power when both appear about equally luminous; and of strong emissive power when the intensity of the light which it emits is greater than that from the platinum. Most solid bodies emit a white light, others—as, for instance, erbia—colored light.

Some bodies, such as many osmium, carbon, and molybdenum compounds, volatilize and separate out finely-

divided solid matter, which renders the flame luminous. Gases and vapors always exhibit a smaller power of emission than fused substances, and these generally less than solid bodies. The form of the substance under examination must always be noted, as the emissive power depends upon the nature of the surface: thus, compact alumina, obtained by slowly heating the hydrate, possesses only a moderate emissive power, whereas the porous oxide prepared by quick ignition of the sulphate possesses a high power of emission.

140. The melting point is determined by using the six different temperatures already mentioned. At every increase of temperature the bead is examined with the lens to see whether the volume is decreased or increased, whether bubbles are given off on melting, whether on cooling the bead is transparent, and what changes of color it undergoes during the action of the heat or on afterward cooling.

Fig. 37.

141. The volatility is ascertained by allowing equally heavy beads of the substance, placed on a platinum wire, to evaporate in the zone of fusion, and observing the time, by means of a metronome, which the bead takes to volatilize. The point at which the whole of the substance is converted into vapor can be ascertained with great accuracy, often to a fraction of a second, by the sudden disappearance of the coloration of the flame. The platinum wire upon which the substance is weighed is protected from the moisture of the air by insertion in a tube (Fig. 37). If we know the weight of the tube and wire, the right weight of substance can easily be attached, either by volatilizing a portion or by fusing some more substance on to

the bead, and thus making it lighter or heavier. The experiments are best made with one centigramme of substance. The position in the flame where the highest constant temperature exists can be found by moving a fine platinum wire, fixed on a stand and bent at its point at a right angle, slowly about the zone of fusion, and noting the point where it glows most intensely. The beads to be volatilized are then most carefully brought into the flame at the same distance from the point of this wire. Care must also be taken that the dimensions of the flame do not undergo change from alterations in the pressure of the gas while the experiments are going on.*

142. Flame-coloration. Many substances which volatilize in the flame may be detected by the peculiar kinds of light which their glowing gases emit. These colorations appear in the upper oxidizing flame when the substance causing them is placed in the upper reducing flame. Mixtures of various flame-coloring substances are tested in the lowest and coldest part of the flame; and here it is often possible to obtain for a few moments the peculiar luminosity of the most volatile of the substances unaccompanied by that of the less volatile constituents.

B. Oxidation and Reduction of Substances.

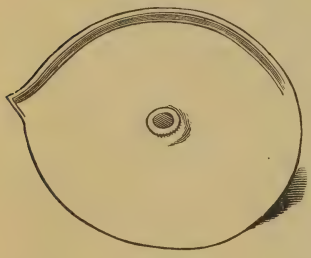
In order to recognize substances by the phenomena exhibited in their oxidation and reduction, and to obtain them in a fit state for further examination, the following methods are employed:

143. Reduction in glass tubes is especially employed for the detection of Hg, or for the separation of S, Se, P, etc., when in combination with Na or Mg. A stock of

* For results of experiments by Hurtzig and Bunsen see *Flammenreactionen*, by R. Bunsen, 1880.

very thin glass tubes is prepared, each 2 to 4 millims. in width and 3 centims. in length. Forty of these are easily made out of one ordinary-sized test-tube, by softening the glass before the blowpipe, and then drawing it out until the requisite size of tube is obtained. This long tube is then cut up with a diamond into pieces 6 to 8 centims. long, and each of these again divided into two over the lamp, and the closed ends neatly rounded. The sample, having been finely powdered with the knife-blade (Fig. 34, *a*) on the porcelain plate (Fig. 38), is treated in a tube either by itself, or with a mixture of carbon and soda, or with **sodium** or **magnesium**. A piece of magnesium wire, a few millims. in length, is for this purpose pushed down into the powdered sample contained in the glass tube; the sodium is carefully freed from naphtha, and rolled out between the fingers to a small cylinder, which is then surrounded by the powdered substance. The best form of carbon is the soot from turpentine which has been deposited upon the outside of a basin filled with cold water. As soon as the small tube containing the perfectly dry sample has been heated to the point of fusion of the glass, when generally an ignition inside the tube is noticed, it is allowed to cool, and then placed upon the porcelain plate, covered by a piece of paper, and crushed to powder with the knife, for the purpose of further examining the products of reduction.

Fig. 38.



144. Reduction on splinters of charcoal. In this way the metal can be obtained in small globules, or as a porous

mass, from quantities often less than a milligramme of the sample.

A transparent crystal of sodium carbonate is brought near to the outside of the flame, and a common wooden lucifer match then rubbed over two-thirds of its length with the drops of fused salt. If the match is then turned upon its axis through the flame, the carbonized wood becomes surrounded with a crust of solid sodium carbonate, which, on heating in the zone of fusion, melts, and is absorbed by the carbon. A splinter of charcoal is thus obtained, which is prevented from burning by its glaze of soda. A mixture of the substance is then made with the knife upon the hand with one drop of the melted soda-crystal, and a portion of this of the size of a mustard-seed placed upon the point of the splinter. As soon as this has been melted in the lower oxidizing flame, it is passed through a part of the dark interior zone to the hotter portion of the lower reducing flame. The point at which the reduction occurs is easily seen by the violent effervescence of the soda; and this is after a time stopped by bringing the splinter into the dark zone. In order to isolate the reduced metal, the end of the splinter is broken off and rubbed up with a few drops of water in a small agate mortar, when the metallic particles are generally visible without removal of the carbon. For further examination, the carbon and soda can be easily removed by several careful washings, and the particles transferred to a small piece of curved glass cut out from an old flask,* in which they are again washed by decantation, the last drops of water removed by suction with a piece of filter-paper, and the metallic particles dried at a moderate heat.

* Watch-glasses crack much too readily to be used for such experiments.

A few tenths of a milligramme of the metal are generally sufficient to yield a solution with which all the characteristic precipitations can be accomplished, the reagents being contained in capillary glass threads, dropped into the solution by the milligramme, and the effect thus produced ascertained by examination with a lens. Iron, cobalt, and nickel, which do not fuse to globules on the splinter, are withdrawn from the agate mortar by means of the point of the magnetized blade (Fig. 134, *b*), washed with water, and dried high above the flame on the point of the knife. If the blade be then tightly drawn between the upper part of the thumb and the lower part of the first finger, and if the point of the blade be then approached to the metallic particles on the finger, they jump from the hand to the blade, forming a brush-like bundle, which can be conveniently examined by the lens, and by touching with a melted borax bead can be transferred in suitable quantities. The portion of metal remaining on the knife is rubbed on to a small piece of filter-paper, a drop of acid added, and the paper warmed over the flame so as to allow the metal to dissolve; this solution can then be further examined with various reagents.

C. Films upon Porcelain.

145. Those volatile elements which are reduced by carbon and hydrogen can be deposited from their compounds as films on porcelain, either in the elementary state or as oxides. Such films can be easily converted into iodides, sulphides, and other compounds, and thus may be made to serve as most valuable and characteristic tests. The films are composed in the centre of a thick layer, which on all sides gradually becomes thinner until the merest tinge is reached; it is therefore necessary to

distinguish between "thick" and "thin" parts of the films. Both exhibit in their variation of thickness all the tints of color characteristic of the substance under different circumstances of division. One-tenth up to one milligramme is in many cases sufficient for these reactions. Many surpass Marsh's arsenic test in delicacy and certainty, and approach in this respect the spectrum-analytical methods.

The following films can be obtained:

146. Metallic films are prepared by holding in one hand a particle of the substance on an asbestos thread in the upper reducing flame, which must not be too large, whilst with the other hand a glazed porcelain basin, one to two decimètres in diameter, filled with cold water, is held close above the asbestos thread in the upper reducing flame. The metals separate out as dead-black or brilliant-black films of varying thickness. Even Pb, Sn, Cd, and Zn yield in this way films of reduced metal, which by mere inspection cannot be distinguished from the soot separated out on the porcelain by a smoky flame. By means of a glass rod, these films can be touched with a drop of dilute HNO_3, containing about 20 per cent. of real acid; and the various degrees of solubility of the films serves as a distinguishing characteristic.

Cadmium, Lead, Zinc, Indium. } The film dissolves quickly.

Bismuth, Mercury, Thallium. } The film dissolves slowly.

Antimony,
Arsenic,
Selenium,
Tellurium. } The film is insoluble.

147. Oxide films are obtained by holding the porcelain basin filled with water in the *upper oxidizing flame*, the rest of the operation being the same as in the production of the metallic films. If only a very small quantity of the sample can be employed, care must be taken to lessen the size of the flame, in order that the volatile products may not be spread over too large a surface of porcelain.

The film of oxide is examined as follows:

(α) The color of the thick and thin film is carefully observed.

(β) The reducing action or otherwise of a drop of stannous chloride is noted.

(γ) If no reduction occurs, NaHO is added to the stannous chloride until the precipitated hydrate redissolves, and then it is to be observed whether a reduction occurs.

(δ) A drop of perfectly neutral silver-nitrate is rubbed over the film with a glass rod, and a current of ammoniacal air is blown over the surface from a small wash-bottle containing ammonia solution, and having the mouth-tube dipping under the liquid and the exit-tube cut off close below the cork. If a precipitate is formed, the color is observed, and the solubility or alteration, if any, noticed, which occurs when the current of alkaline air is continued, or when a drop of ammonia liquor is added.

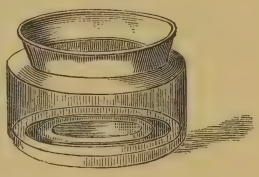
148. Iodide films are simply obtained from the oxide films by breathing on the latter upon the cold basin, which is then placed upon the wide-mouthed, well-stop-

pered glass (Fig. 39), containing fuming hydriodic acid and phosphorous acid derived from the gradual deliquescence of phosphoric tri-iodide. When the mixture no longer fumes, owing to absorption of moisture, it is easy to render it again fuming by adding a little phosphoric anhydride. Other films, often containing both iodides of a metal, and therefore frequently less regular in color and appearance, may be easily obtained by smoking the oxide film with a flame of alcohol containing iodine in solution, placed upon a bundle of asbestos threads, and held under the basin. If any iodine be condensed on the basin with the HI, it can easily be removed by gentle warming and blowing.

The examination of the film is conducted as follows:

(α) The solubility of the film is examined simply by breathing upon it when the basin is cooled; the color then either changes or entirely disappears, the film being dissolved in the moisture of the breath. If the basin be gently warmed, or if it be blown upon for some distance, the film again becomes visible by the evaporation of the moisture in the current of air.

Fig. 39.



(β) The ammonium compound of the iodide is formed by blowing ammoniacal air upon it, and noticing whether the color of the thick and thin films alters quickly, slowly, or not at all. The different colors reappear at once if the basin be held for a few moments over an open bottle containing fuming HCl.

(γ) The iodide films generally give the same reactions

TABLE OF VOLATILE ELEMENTS WHICH CAN

	METAL FILM.	OXIDE FILM.	OXIDE FILM WITH STANNOUS CHLORIDE.	OXIDE FILM WITH STANNOUS CHLORIDE AND SODIUM HYDRATE.	OXIDE FILM WITH SILVER-NITRATE AND AMMONIA.
Te	Black; thin part brown.	White.	Black.	Black.	Yellowish-white.
Se	Cherry-red; thin part brick-red.	White.	Brick-red.	Black.	White.
Sb	Black; thin part brown.	White.	White.	White.	Black; insoluble in ammonium hydrate.
As	Black; thin part brown.	White.	White.	White.	Lemon-yellow or reddish-brown; soluble in ammonium hydrate.
Bi	Black; thin part brown.	Yellowish-white.	White.	Black.	White.
Hg	Gray non-coherent thin film.				
Tl	Black; thin part brown.	White.	White.	White.	White.
Pb	Black; thin part brown.	Yellow-ochre color.	White.	White.	White.
Cd	Black; thin part brown.	Blackish-brown; thin part white.	White.	White.	White; in the thin parts turns bluish-black.
Zn	Black; thin part brown.	White.	White.	White.	White.
Sn	Black; thin part brown.	Yellowish-white.	White.	White.	White.

BE REDUCED AS FILMS ON PORCELAIN.

IODIDE FILM.	IODIDE FILM WITH AMMONIUM HYDRATE.	SULPHIDE FILM.	SULPHIDE FILM WITH AMMONIUM SULPHIDE.	FLAME-COLORATION.	
Brown; disappears for a time on breathing.	Disappears altogether on blowing.	Black to blackish-brown.	Disappears for a time.	Upper reducing flame, pale-blue: upper oxidizing flame, green. No odor.	Elements whose reduction films are scarcely dissolved in dilute nitric acid.
Brown; does not wholly disappear on breathing.	Does not disappear on blowing.	Yellow to orange.	Orange, and then disappears for a time.	Cornflower-blue. Odor of rotten horse-radish.	
Orange-red to yellow; disappears on breathing.	Disappears altogether on blowing.	Orange.	Disappears for a time.	Upper reducing flame, pale-greenish. No odor.	
Orange-yellow; disappears for a time on breathing.	Disappears altogether on blowing.	Lemon-colored.	Disappears for a time.	Upper reducing flame, pale-blue. Odor of garlic.	
Bluish-brown; thin parts pink; disappear for a time on breathing.	Pink to orange; chestnut-colored when blowing.	Burnt-umber-color to coffee-colored.	Does not disappear.	Bluish; not characteristic.	Elements whose reduction films are with difficulty dissolved in dilute nitric acid.
Carmine-colored and lemon-yellow; does not disappear on breathing.	Disappears for a time on blowing.	Black.	Does not disappear.		
Lemon-yellow; does not disappear on breathing.	Does not disappear on blowing.	Black; thin parts bluish-gray.	Does not disappear.	Light grass-green.	
Orange-yellow to lemon-color; does not disappear on breathing.	Disappears for a time on blowing.	Brownish-red to black.	Does not disappear.	Light-blue.	Elements whose reduction films are instantly dissolved in dilute nitric acid.
White.	White.	Lemon-colored.	Does not disappear.		
White.	White.	White.	Does not disappear.		
Yellowish-white.	Yellowish-white.	White.	Does not disappear.	Intense indigo-blue.	

as the oxide films with silver nitrate and ammonia, with stannous chloride, and with caustic soda.

149. The sulphide film is most easily obtained from the iodide film by blowing upon it a current of air saturated with ammonium sulphide, and removing the excess of sulphide by gently warming the porcelain. It is advisable to breathe on the film from time to time whilst the current of sulphuretted air is being blown on the basin. The experiments to be made with this film are:

(α) The solubility or otherwise in water is ascertained by breathing on it, or by addition of a drop of water. The sulphides often possess the same color as the iodide films; they may, however, generally be distinguished by their insolubility on breathing.

(β) The solubility of the sulphide in ammonium sulphide is ascertained by blowing or dropping.

150. Films on test-tubes. Under certain circumstances it is advisable not to collect the film on porcelain, but upon the outside of a large test-tube (Fig. 35, D); this method is especially used when it is needed to collect larger quantities of the reduction film for the purposes of further examination. The fine asbestos thread with the sample of substance is held on the glass tube (b) before the lamp, so that it is placed at the height of the middle of the upper reducing flame, and the test-tube fixed so that the lowest point is just above the end of the asbestos thread. If the lamp be now pushed under the test-tube, the substance and the asbestos thread are in the reducing flame. By repeating this operation, the film can be obtained of any desired thickness; some pieces of marble are in this case placed in the test-tube, to prevent the water from being thrown out of the tube by percussive boiling.

THE REACTIONS OF THE ELEMENTS.

The elements, which can easily be recognized by their flame reactions, are arranged in the following groups and sub-groups according to their behavior in the reducing and oxidizing flames:

A. **Elements whose compounds are reducible to metal and form a film on porcelain** (see page 143):

1. Films scarcely soluble in cold dilute nitric acid (containing about 20 per cent. of acid)—*tellurium, selenium, antimony, arsenic* (pages 143–146).
2. Films slowly and difficultly soluble in cold dilute nitric acid—*bismuth, mercury, thallium* (pages 146–148).
3. Films instantly soluble in cold dilute nitric acid—*lead, cadmium, zinc, indium* (pages 148, 149).

B. **Elements whose compounds are reduced to metal, but form no film:**

1. Not fusible to a metallic bead after reduction.
   a. Magnetic—*iron, nickel, cobalt* (pages 150, 151).
   b. Non-magnetic—*palladium, platinum, rhodium, iridium, osmium* (pages 151, 153).
2. Fusible to metallic beads—*gold, silver, copper, tin* (pages 153, 154).

C. **Elements most easily separated and recognized as compounds**—*Molybdenum, tungsten, titanium, tantalum, niobium, chromium, vanadium, manganese, uranium, silicon, phosphorus, sulphur* (pages 155–162).

A. ELEMENTS WHOSE COMPOUNDS ARE REDUCIBLE TO METAL, FORMING A FILM UPON PORCELAIN.

151. Tellurium compounds. *Flame-coloration,* in upper

reducing flame, pale-blue, whilst the oxidizing flame above appears green.

Volatilization, unaccompanied by any odor.

Reduction film, black, with dark-brown coating, dull or brilliant; heated with concentrated sulphuric acid, gives a carmine-red solution.

Oxide film, white, scarcely or not at all visible; stannous chloride colors it black, by reason of separated tellurium; silver nitrate, after ammonia has been blown upon it, yellowish-white.

Iodide film, dark-brown, with brown coating; disappears momentarily when breathed upon, but not when slightly warmed; reappears on exposure to HCl; blackened by $SnCl_2$.

Sulphide film, dark-brown to black; does not disappear when breathed upon; dissolves in NH_4HS blown upon it, and reappears upon warming or if blown upon with air.

With soda on charcoal splinter gives a sodium telluride, which, when moistened upon a silver coin, produces a black spot; and if the specimen contains much tellurium, with HCl, diffuses an odor of hydrogen telluride with the separation of black tellurium.

152. Selenium compounds. *Flame-coloration*, pure azure-blue.

Volatilizes, burning with the odor of selenium.

Reduction films, brick-red to cherry-red; at one time dull, at another brilliant; gives, when heated with concentrated H_2SO_4, a dirty-green solution.

Oxide film, white; brick-red from separated selenium when $SnCl_2$ is dropped upon it; the old color darkened by NaHO; with $AgNO_3$ the oxide film gives a white,

scarcely visible, coloration, which disappears when ammonia is blown upon it.

Iodide film, brown; contains some reduced selenium, and therefore cannot be made to disappear completely, either by breathing upon it or by blowing ammonia upon it.

Sulphide film, yellow to orange-red; insoluble in water, soluble in NH_4HS.

With soda on charcoal splinter gives sodium selenide, which produces, with a drop of water, a black spot upon a silver coin, and moistened with HCl, if the quantity is not too small, gives the odor of hydrogen selenide, with separation of red selenium.

153. Antimony compounds. *Flame-coloration*, by treatment in the upper reducing flame, pale-green, unaccompanied by any smell.

Reduction film, black; sometimes dead, sometimes bright.

Oxide film, white; moistened with a perfectly neutral solution of $AgNO_3$, and then blown on by ammoniacal air it gives a black spot which does not disappear in NH_4HO. If the film be first placed over bromine vapor the reaction cannot be obtained, owing to the oxidation of Sb_2O_3 into Sb_2O_5. It is unaltered by $SnCl_2$, either with or without NaHO.

Iodide film, orange-red, disappearing by breathing, and reappearing by blowing or warming; blown on with ammoniacal air it disappears, but does not return. Generally it gives the same reactions as the oxide.

Sulphide film, orange-red. The film is difficult to blow away with NH_4HS; returns on blowing with air; insoluble in water.

With soda on charcoal splinter gives no black stain on silver, but yields a white, brittle, metallic bead.

154. Arsenic compounds. *Flame-coloration,* in upper reducing flame, pale-blue, giving the well-known arsenical smell.

Reduction film, black, dead, or brilliant; thin film brown.

Oxide film, white; touched with a perfectly neutral solution of $AgNO_3$, and then blown with ammoniacal air it gives a canary-yellow precipitate, soluble in NH_4HO. Together with this yellow precipitate, a brick-red one of silver arsenite occurs when the film has previously been treated with bromine vapor. $SnCl_2$, with and without soda, produces no change.

Iodide film is deep-yellow; disappears on breathing, but returns on drying; disappears in ammoniacal air, and does not return; reappears unaltered after the action of HCl.

Sulphide film, lemon-yellow; disappears easily on blowing with NH_4HS, and reappears on warming or blowing; insoluble in H_2O, and does not disappear by blowing upon it.

Reduction on charcoal splinter yields no metallic bead.

155. Bismuth compounds. *Reduction film,* black, dead, or brilliant; thin portion of film, brownish-black.

Oxide film, light-yellow; unaltered by $AgNO_3$, with or without ammonia; gives no reaction with $SnCl_2$, but yields black precipitate of $BiHO_2$ on addition of NaHO.

Iodide film is very characteristic, and remarkable for the number of tints which it assumes. The thick part is of a brown or blackish-brown color, with a shade of lavender-blue; the thin film varies from flesh-color to light-pink; it easily disappears on breathing, and appears again on blowing. In a stream of ammoniacal air it passes from pink to orange, and on blowing or warming it again, at-

tains a chestnut-brown color; it resembles the oxide film in its behavior with $SnCl_2$ and NaHO.

Sulphide film is of a burnt-umber color; the thin parts are of a lighter coffee-brown color; does not disappear on blowing, and is not soluble in NH_4HS.

On charcoal splinter with soda the bismuth compounds are reduced to a metallic bead, yielding, when rubbed in the mortar, bright, shining, yellowish splinters of metal soluble in HNO_3. The solution gives, with $SnCl_2$ and NaHO, black $BiHO_2$.

156. Mercury compounds. *Metallic film* is mouse-gray, non-coherent, and spreads over the whole basin. To obtain small traces of Hg in the reduced state, the sample is mixed with soda and KNO_3 and filled into a thin test-tube five to six millims. wide and ten to twenty millims. long. This is held by a platinum wire in the flame, whilst the bottom of the basin, filled with cold water, is placed close above the open end of the tube. If the quantity of Hg is considerable, it collects in the form of globules, which can be seen with a lens, and which can be collected into larger drops by wiping the basin with a piece of moistened filter-paper.

Iodide film is obtained by breathing on the metallic film, and then placing it over the vessel (Fig. 39, page 139) containing moist Br. It first becomes black, and then disappears, but not until after some time; HgBr is formed. If the basin be now placed above the vessel of fuming HI, a very characteristic carmine-colored film of Hg_2I is produced; this is often accompanied by HgI, but neither of these disappear when breathed upon or when blown upon with ammoniacal air.

Sulphide film, black; not altered by breathing or by blowing with NH_4HS.

157. Thallium compounds. Since the minutest trace of this element can be recognized by means of the spectroscope, it will seldom be detected in any other way.

Flame coloration, bright grass-green.

Metallic film, black, with coffee-brown coating.

Oxide film, colorless; unchanged by $SnCl_2$ or NaHO; also with $AgNO_3$ with or without NH_4HO.

Iodide film, lemon-yellow; insoluble in NH_4HO.

Sulphide film, obtained from the oxide film, black, with livid coating; insoluble in NH_4HS.

On charcoal with soda, reducible to a white ductile grain.

158. Lead compounds. *Flame-coloration*, pale-blue.

Reduction film, black, dead, or brilliant.

Oxide film, bright yellow-ochre colored; stannous chloride gives no reaction even on addition of NaHO; $AgNO_3$ does not produce any reaction, either alone or on addition of NH_4HO.

Iodide film, orange- to lemon-yellow; insoluble on breathing or on moistening; disappears on blowing with ammoniacal air, and again appears on warming.

Sulphide film, brownish-red to black; by blowing or moistening with NH_4HS it remains unaltered.

On charcoal splinter with soda gives a gray, very soft, ductile metallic bead, which is slowly but completely soluble in HNO_3, yielding a white, easily-crystallizable salt, soluble in H_2O, and precipitated as a white powder on addition of HSO_4 from a capillary tube.

159. Cadmium compounds. *Metallic film*, black; the thin parts, brown.

Oxide film, brownish-black, shading off through brown to a white invisible film of oxide, which is not changed by $SnCl_2$, alone or with soda; $AgNO_3$ produces a black-

ish-blue coloration of reduced metal, which is very characteristic, and does not disappear on addition of NH_4HO.

Iodide film, white; no change produced by NH_4HO.

Sulphide film, lemon-yellow; insoluble in NH_4HO.

Reduction on charcoal splinter with soda. The metal, owing to its volatility, can be obtained only with difficulty as a silver-white, ductile bead.

160. Zinc compounds. *Reduction film*, black; in the thin parts, brown.

Oxide film, white, and therefore invisible. To test it, a square centimetre of filter-paper, moistened with HNO_3, is rubbed over the surface, and then rolled up on two rings on fine platinum wire, three millimètres in diameter, and burnt. If the paper is burnt in the upper oxidizing flame at as low a temperature as possible, the ash forms a small solid mass about a square millimètre in area, which can be ignited without fusion, and becomes yellow on gently heating, and appearing white on cooling. If this be moistened with a few milligrammes of very dilute cobalt solution and ignited, it appears of a beautiful green color on cooling; the same reaction can be effected with the metallic film.

Iodide film, white; not clearly recognizable either alone or after ammonia has been blown upon it.

Sulphide film, also white, and not easily recognized either alone or when moistened with NH_4HS.

Reduction on charcoal splinter does not proceed on account of volatility of the zinc.

161. Indium compounds. Detected with most ease and certainty with the spectroscope.

Flame-coloration, intense; pure indigo-blue.

Metallic film, black, with brown coating; at one time dull, at another brilliant. Disappears instantly with HnO_3.

Oxide film, yellowish-white; scarcely visible; give no reactions with $SnCl_2$ and $AgNO_3$ solution.

Iodide film, also yellowish, nearly white; invisible, if weak, with and without ammonia.

Sulphide film, also yellowish; nearly white, scarcely visible. Unchanged by NH_4HS.

Reduction on charcoal splinter with soda takes place with difficulty, and affords silver-white, ductile globules, slowly soluble in HCl.

B. ELEMENTS WHOSE COMPOUNDS ARE REDUCED TO THE METALLIC STATE, BUT FORM NO FILM.

1. *METALS NOT FUSED TO A BEAD AFTER REDUCTION.*

a. Magnetic metals.

162. Iron compounds. *Reduction on charcoal splinter* gives no metallic bead or ductile lustrous particles; the finely-divided metal forms a black brush on the end of the magnetized knife-blade; this, when rubbed off on paper and dissolved in a drop of aqua regia, yields a yellow spot when warmed over the flame, which, when moistened with potassium ferrocyanide, gives a deep coloration of *Prussian blue*. The yellow spot, moistened with NaHO, and then held for a few moments in a vessel with bromine vapor, gives, on a second addition of soda, no coloration of a higher oxide.

Borax bead. In the oxidizing flame, when hot, yellow to brownish-red; when cold, yellow to brownish-yellow; reducing flame, bottle-green.

163. Nickel compounds. *Reduction on the charcoal splinter.* On pulverizing the charcoal, white, lustrous, ductile, metallic particles are obtained, forming a brush on the

magnetized blade. The metal, dissolved in HNO_3 on paper, gives a green solution, which, on moistening with soda, exposure to bromine vapor, and second addition of soda, give a brownish-black spot of Ni_2O_3. The ash of the paper, from which the soda has been washed out, can be used for the borax-bead test.

Borax bead. Oxidizing flame, grayish-brown or dirty-violet. Upper reducing flame, gray, from reduced Ni, which often collects to a spongy mass of metal, rendering the bead colorless.

164. Cobalt compounds. *Reduction on charcoal splinter.* By pulverizing the charcoal, white, ductile, lustrous, metallic particles are obtained, which form a brush on the magnetic blade. The metal, rubbed off on to paper, gives a red solution when moistened with HNO_3; this yields a green color on addition of HCl and drying, which disappears again on moistening. The paper, moistened with soda, brought into bromine vapor, and again moistened with soda, yields a brownish-black spot of Co_2O_3. This reaction is plainly seen with a few tenths of a milligramme of metal. The paper can also be used, after washing out the soda and burning, for the coloration of the borax bead.

Borax bead. Deep-blue bead in the oxidizing flame, which does not change in the lower reducing flame. When treated for a considerable time alone, or, better still, with ammonium platin-chloride, in the most energetic upper reducing flame, is completely decolorized, but only after long treatment, with the separation of cobalt or platin-cobalt.

b. Non-magnetic metals.

165. Palladium compounds. These are reduced upon fine *platinum wire, with soda,* in the upper oxidizing

flame, to a gray mass, similar to platinum sponge, which, when rubbed in an agate mortar, gives shining, ductile, metallic scales. The scales, rinsed and dried upon a piece of glass plate, dissolve in HNO_3, with reddish-brown color.

If a small drop of a solution of mercuric cyanide is added to the liquid, a white flocculent precipitate is obtained, which dissolves in NH_4HO when dropped upon it. After evaporation and boiling with aqua regia, the liquid, evaporated to a small drop, gives a dirty orange-yellow, crystalline precipitate of palladium ammonio-chloride.

Solution of palladium is colored blue, green, and brown by $SnCl_2$, according to the amount used.

166. Platinum compounds. These give, when *ignited upon platinum wire with soda* in the upper oxidizing flame, also a gray spongy mass, which, by rubbing in an agate mortar, is converted into shining, silver-white, ductile, metallic scales. These are insoluble either in HNO_3 or HCl alone, but with aqua regia give a bright-yellow solution if the platinum is pure; if it contains rhodium, iridium, or palladium, they give a brownish-yellow solution. When solution of mercuric cyanide is added to the solution and ammonia blown upon it, no flocculent white precipitate is formed, but immediately a bright-yellow crystalline precipitate of ammonium platin-chloride.

$SnCl_2$ colors solutions of platinum yellowish-brown.

167. Iridium compounds. These, ignited in the upper oxidizing flame with soda, are likewise reduced to metal, which, when rubbed in an agate mortar, forms a gray powder without lustre, and not in the least degree ductile. This is insoluble in nitric acid, hydrochloric acid, and aqua regia.

168. Rhodium compounds. These are only distinguished from the iridium compounds by the fact that the metallic powder, insoluble in aqua regia, when fused with acid potassium sulphate, is partially oxidized, and affords a rose-red solution.

169. Osmium compounds. These give in the oxidizing flame volatile osmium tetroxide of a pungent odor, similar to chlorine, and which irritates the eyes.

2. *METALS FUSED TO A BEAD AFTER REDUCTION.*

170. Gold compounds. If only traces of gold are present, mixed with a considerable quantity of gangue, it can only be concentrated and detected according to the old processes for detecting gold. Otherwise even a few tenths of a milligramme can be recognized by reduction with soda on a charcoal splinter. The yellow, shining, ductile, metallic grain obtained in this way can be reduced to spangles having the lustre of gold by rubbing in an agate mortar. These are insoluble in HCl or HNO_3, but give rather readily, with aqua regia, a bright-yellow solution. If this is soaked up into a piece of filter-paper and touched with $SnCl_2$, purple of Cassius is formed. What remains upon the glass is colored brown by a solution of $FeSO_4$, by reason of separated gold, whilst the liquid appears blue by transmitted light.

171. Silver compounds. If silver occurs only in traces in slags or complex ores, it can only be detected by the well-known method of cupellation. If, however, the silver compound is not mixed with a very large amount of foreign matter, it can be detected in very minute quantities by reduction with soda on the charcoal splinter. The

white ductile beads dissolve easily on warming in dilute HNO_3, and yield AgCl with HCl, which can then readily be recognized by its behavior with HNO_3 and NH_4HO. Less than one-tenth of a milligramme of silver can thus be easily detected with certainty.

172. Copper compounds. *On the charcoal splinter with soda* the copper compounds yield a ductile, lustrous metallic bead, easily recognizable by its red copper-color. By rubbing in the mortar, flat metallic particles are obtained, which can be readily washed, and are easily soluble in HNO_3. The blue solution, absorbed on filter-paper, yields a brown stain on addition of potassium ferrocyanide. Instead of acting upon a metal in a curved glass, it may be dissolved by moistening paper upon which it is placed with HNO_3.

With borax on platinum wire. Blue bead, not altered to cuprous oxide when heated in the lower reducing flame alone, but on addition of very little tin oxide, forms a reddish-brown bead. If this bead be frequently oxidized and reduced in the flame, a ruby-red transparent bead is obtained; this occurs most readily when the bead is allowed to oxidize very slowly.

173. Tin compounds. *On the charcoal splinter* the Sn compounds are easily reduced to white, lustrous, ductile, metallic beads. The flattened particles, transferred to the curved glass, slowly dissolve in HCl; and the solution, when absorbed by paper, gives a red precipitate with selenious, and a black precipitate with tellurous acid, dissolved in HCl. If to the solution a trace of bismuth-nitrate be added, an excess of soda gives a black precipitate of Bi_2O_3. The metal, acted on by HNO_3, yields a white powder of insoluble metastannic acid.

A borax bead, containing enough CuO to render it

faintly blue, serves as a delicate test to ascertain with certainty the presence of a trace of a Sn compound, as the bead, placed in the lower reducing flame, turns reddish-brown or forms a clear ruby-red glass.

C. ELEMENTS MOST EASILY DETECTED BY THE REACTIONS OF THEIR COMPOUNDS.

a. Metallic substances.

174. Molybdenum compounds. *On a charcoal splinter with soda* are reduced, with great difficulty, to a gray powder. In the same way some compounds give in the upper reducing flame a film on porcelain, which it is difficult to obtain. Molybdenum is best recognized as follows:

a. The sample is finely pulverized with the knife on the porcelain plate, is mixed on the hand with soda, obtains a pasty state by fusion. The mixture is then transferred to a spiral of fine platinum wire and fused in the flame. The liquid fused mass is then knocked off the wire and allowed to fall upon the plate, when it is digested with two or three drops of water, and the clear liquid above the sediment is soaked up into three or four strips of filter-paper, not too fine, several millimètres broad. One of these strips, moistened with HCl, does not change color, but with a drop of potassium ferrocyanide is changed to reddish-brown.

If one of these strips is gradually moistened with a few milligrammes of $SnCl_2$, it either becomes blue in the cold or upon warming; if it becomes yellow or yellowish-brown, more of the solution of the test specimen must be added by means of a capillary pipette, in order to cause the blue color to appear.

A drop of NH_4HS, placed upon the third strip, produces a brown color, and on addition of HCl a brown precipitate, whereupon the paper often becomes blue on the edge of the precipitate.

The yellow phosphate precipitate produced by the nitric acid solution of ammonium molybdate can also be readily obtained. The slightly borax bead is colorless in the oxidizing flame; when it contains more molybdenum, bluish, enamel-like; in reducing flame dark, by reason of reduced molybdenum.

175. Tungsten compounds. The reduction of tungsten can also be made on *charcoal splinter with soda*, but is not adapted to the separation or detection of the metal. The compounds are therefore treated in the manner just given for molybdenum, by soaking up the fluid, after fluxing with soda, with strips of filter-paper.

One strip, moistened with HCl, remains white, but if heated, turns yellow; moistened with potassium ferrocyanide, unchanged. A second strip, touched with $SnCl_2$, is colored blue even when cold or on warming. A drop of NH_4HS causes no precipitate alone or with HCl; the paper, however, becomes blue or greenish on warming.

176. Titanium compounds. These give a colorless bead with salt of phosphorus in the oxidizing flame, which turns a pale-amethystine color in the reducing flame. On addition of $FeSO_4$ the bead assumes in the reducing flame the peculiar red color of venous blood, whilst in the oxidizing flame the light-brown color of Fe_2O_3 can be obtained at pleasure. The titanium compounds form with soda a bead, which at first effervesces, and when hot is colorless and transparent, but on cooling becomes opaque. If to the hot bead $SnCl_2$ be added, and if it then be heated

in the lower reducing flame, a gray mass is formed, which dissolves on heating in HCl, yielding a pale amethystine-colored solution.

177, 178. Tantalum and niobium compounds. These manifest the same reactions as titanium.

179. Chromium compounds. In platinum spiral with soda, the compounds when fluxed, with the repeated addition of potassium nitrate, give a bright-yellow mass, which, when knocked off on to the porcelain plate and crushed, give a bright-yellow solution. If this solution is decanted from the residue, and acetic acid added, it becomes yellowish-red, and gives with lead salts, when it is soaked up by strips of filter-paper, a yellow precipitate; with solutions of salts of mercury oxide, a red one; and with $AgNO_3$, a reddish-brown one.

With NH_4S, also by evaporation with aqua regia upon the porcelain plate, the solution becomes green; likewise with $SnCl_2$. The *borax bead* becomes emerald-green in the oxidizing flame, and does not change this color in the reducing flame.

180. Vanadium compounds. Treated with soda and *potassium nitrate in a platinum spiral*, yield a bright-yellow mass, the solution of which, on addition of $AgNO_3$ and acetic acid, yields a yellow precipitate. The fused mass, when evaporated with aqua regia, gives a yellow instead of a green solution, which becomes blue on addition of $SnCl_2$. If much vanadium is present, the solution gives a yellowish-brown solution or precipitate on addition of concentrated cold HCl. In the *borax bead* these compounds give a yellowish-green color in the oxidizing flame; in the reducing flame, a green color.

181. Manganese compounds. *Borax bead.* Amethyst in the oxidizing flame; colorless in the reducing flame.

With sodium carbonate on platinum wire, a bead is formed green after cooling, especially easily after addition of potassium nitrate. Water extracts a green solution from it, which becomes red after the addition of acetic acid, and then, often with the separation of brown flakes, becomes colorless.

182. Uranim compounds give a yellow bead in the oxidizing flame, which becomes green in the reducing flame, especially on addition of $SnCl_2$. These colors closely resemble those of the iron compounds, but may easily be distinguished, at least if no other coloring metallic oxide is present, by the fact that the uranium bead, when incandescent, emits a bluish-green light, analogous to that which the uranium compounds exhibit when fluorescing. Beads of lead oxide, stannic acid, and a few other substances exhibit a similar phenomenon when incandescent, but they do not yield, like uranium compounds, a colored bead on cooling.

Heated gently on the *platinum spiral with* $HKSO_4$, the insoluble uranium compounds can be decomposed. The melted mass is powdered with a few particles of crystallized sodium carbonate, and the moistened mass is absorbed by filtering paper. A brown spot is formed by the addition of a drop of potassium ferrocyanide to the moistened paper.

b. Non-metallic substances.

183. Silicon compounds. The silicates, when treated in the oxidizing flame with sodium carbonate, dissolve more or less with effervescence. The hot fused, when moistened with $SnCl_2$ and thoroughly ignited, does not give a trace of a blue coloration when evaporated upon the porcelain plate, whereby the silica may be distinguished from titanic, tantalic, and niobic acids. It likewise fails to give

the blood-red coloration in a bead with iron sesquioxide, produced by these acids. The fluxed mass, if water and acetic acid are carefully added, and then evaporated on the porcelain plate, separates gelatinous hydrated silica. Fine splinters of silicate give, upon fusing in the bead of salt of phosphorus, a gelatinous skeleton of silica, floating in the fused or cooled bead.

184. Phosphorus compounds. These may easily be detected in its compounds, even when they are mixed with large quantities of other substances, as follows:

The sample, having been ignited, is rubbed fine on the porcelain plate (see Fig. 38), and is then introduced into a small glass tube of the thickness of a straw; into this tube, which is closed at the bottom, a piece of magnesium wire, about one-fourth of an inch in length, is placed so that it is covered by the powder. On heating the tube, magnesium phosphide is formed with incandescence. The black contents of the tube powdered on the plate give, on moistening with H_2O, the highly-characteristic smell of H_3P. A piece of sodium may be substituted for the magnesium wire.

If it has been ascertained that the sample does not yield any film on porcelain in the upper oxidizing flame, the phosphates may be recognized by heating on platinum with borax and a thin piece of iron wire in the hottest part of the reducing flame, when a bright molten bead of iron phosphide is obtained, which can be extracted with the magnetized knife on crushing the bead under paper.

185. Sulphur compounds. *On a charcoal splinter with soda*, in the lower reducing flame, they give a fused mass, which, moistened upon a piece of silver, blackens it. Since selenium and tellurium produce the same reaction, the absence of these substances must be deter-

mined by the absence of a tellurium or selenium spot upon porcelain.

When only metallic sulphides are to be considered, and not sulphates, it will answer simply to heat the test specimen in the flame to detect sulphur by the odor.

EXAMPLES SHOWING THE APPLICATION OF THE FOREGOING METHODS.

186. *a.* **A mixture of sulphide of arsenic, sulphide of antimony, and sulphide of tin.** If in a mixture of these three sulphides, containing only traces of Sb and Sn, they are separated according to the ordinary rules of qualitative analysis, by dissolving in alkaline sulphides and reprecipitation with acids, the detection of these two metals by the regular tests is extremely uncertain and troublesome. According to the following method the detection of these metals is rendered easy and certain when the proportion of Sn is only a few thousandths, and that of the Sb only a few hundredths, of the total weight of the mixture.

Three decigrammes of the sulphides are roasted on a curved piece of glass* small enough to be altogether surrounded by the flame, and the residue, weighing only a few milligrammes, is scraped together with the knife. The moistened mass is then collected on the end of a thread of asbestos and a strong metallic film obtained on the test-tube. In order to prevent the deposition of any carbon with the metals, which would act injuriously in the subsequent operations, the upper reducing flame is made so small that the luminous point is only just visible. The film is next dissolved in a drop or two of HNO_3 in the curved rim (Fig. 38, page 134), and the solution evaporated below its boiling-point by gently

* Pieces of a thin chemical flask are also best for use in this case.

warming and blowing, so as to obtain the solid residue in as small a space as possible. A drop of neutral silver solution is now brought on to the residue at the moment when it becomes solid; and on blowing with ammoniacal air a characteristic black stain is formed, whilst the reaction of As is also generally noticed.

In order to detect Sn, a few scarcely visible particles of the roasted sulphides are fused on to a borax bead which has been very slightly tinted with cupric oxide. If the bead is now brought into the lower reducing flame, it becomes a ruby-red color from reduced cuprous oxide. If the oxide be present in too large a quantity, the bead can be obtained transparent by the process described under the reactions of the copper compounds. This reaction can only be obtained in the lower reducing flame of the non-luminous gas-lamp, as in the ordinary blowpipe flame the cupric oxide is reduced to cuprous oxide without the presence of tin-salt.

187. *b.* **Black tellurium, containing tellurium, selenium, antimony, gold, lead, and sulphur,** After the sulphur has been detected by the smell by roasting, the metallic film is obtained on a test-tube, which is then placed inside a wider and shorter tube containing a few drops of *concentrated* sulphuric acid, so that the metallic film is surrounded by the acid. If the temperature be now gradually raised the presence of tellurium is at once ascertained by the formation of a bright carmine color. If the temperature be still further raised, the tellurium oxidizes and the olive-green color of selenium becomes visible; the cooled solution, on dilution with water, then no longer exhibits the black precipitate of tellurium, but is colored yellowish-red with the selenium. If this is present in small traces only, it can be best detected by looking

down the length of the test-tube upon a sheet of white paper. As common commercial H_2SO_4 often contains traces of selenium, it is well to make a trial experiment first. The antimony is detected as in preceding example. To detect the lead and gold, a sample is reduced on the charcoal splinter, the beads of the alloy are washed into a curved glass, and the flattened and dried metallic particles treated with rather strong HNO_3 as long as anything dissolves. The acid is then evaporated off, and the soluble portion of the residue dissolved in a drop or two of water. The solution is brought on to a second curved glass by means of a capillary pipette, and the characteristic precipitate of lead sulphate obtained with H_2SO_4. The gold left undissolved as a brown powder is completely washed by frequent addition of water and removal of the same with the capillary pipette. A portion of the dried particles of gold fused on a charcoal splinter with soda yields in the mortar bright-yellow, golden particles, which may be dissolved in aqua regia and tested with $SnCl_2$. A centigramme of the sample is sufficient in experienced hands for all these reactions.

SPECTRUM ANALYSIS.

188. The second method—that of *spectrum analysis*, discovered by Kirchhoff and Bunsen—consists in letting the rays of the colored flame, after passing through a narrow slit, traverse a prism, and in observing the spectrum thus produced by means of a telescope. Each of the metals which give color to the flame thus yields a peculiar spectrum, formed in some cases, as in that of barium, of many contiguous colored lines; in others, of two more distant lines of different color, as shown by lithium; or, again, of a single line, as in case of sodium and

thallium. These spectra are characteristic in two respects —viz. 1, in the definite color of the spectrum lines; and 2, in the invariable relative position they occupy.

The last-named fact enables us to detect, without difficulty in most cases, all the spectrum-giving ingredients of a mixture. Thus, when potassium, sodium, and lithium-salts are brought together into the *spectroscope*, the lines characteristic of each metal appear in the utmost purity at one view. Very minute traces of some elements do not however, exhibit their spectra in presence of large quantities of other substances.

The methods of obtaining the spectra of the elements or their compounds vary according to their volatility. The instrument or spectroscope used varies according to the degree of accuracy which the observations require. The direct-vision pocket spectroscope may be used for most blowpipe investigations. Although it has no scale, the relative positions of the various lines can be easily determined from the table.

A much more powerful and perfect spectroscope, exclusive of the source of light, is composed of an adjustable slit, a contrivance (collimating lens) for rendering the rays parallel that have passed through the slit, and a prism. All light except that under examination must be excluded from the prism, and therefore the slit, prism, and lenses are enclosed in a tube, or, if the prism be too large, the latter is fitted with a separate cover. As the spectrum on emerging from the prism is but little longer than the width of the slit, and only becomes of some length as the distance from the prism increases, a magnifying-glass is introduced, in order that the eye, though at but a small distance from the prism, may see the spectrum of a sufficiently large size, and the spectrum, there-

fore, is not observed with the naked eye, but through the medium of a telescope of moderate power. This telescope is also necessary for enabling the eye to receive the whole of the light passing from the collimating lens through the prisms.

In order to know the exact position of the lines another tube is added, in the end of which is placed a scale photographed on glass, and which is so reflected that the observer sees the scale and spectrum at the same time.

A small glass prism may also be attached to the end of the tube through which the colored flame is admitted, so that the spectra of two flames may be examined and compared at the same time.

Not only the number of the spectrum lines of a substance, but also the degree of their intensity, is deserving of careful attention. As the brilliancy of the lines increases with the temperature, so, as a rule, it is those lines which are particularly prominent at a high degree of temperature that are the first to appear at a low temperature. These are best suited for the recognition of a substance, and are therefore called *characteristic* lines. Such lines, according to their brightness, are designated in each substance by the letters of the Greek alphabet, α, β, γ, δ, etc., being affixed to the symbol of the element.

The table at the beginning of the book exhibits the spectra of some of the more commonly occurring and easily recognized elements.

189. Potassium. All the volatile compounds of potassium, when placed in the flame, give a widely-extended, continuous spectrum, which consists of two chief lines; one line Kα, situated in the outermost red, and a second line, Kβ, situated far in the violet rays toward the other end of the spectrum.

When vapor of potassium is heated in the electric spark, several other lines make their appearance. Before testing potassium silicates they should be ignited with sodium carbonate, as it does not interfere with the reaction. Orthoclase, sanidin, and adularia may be easily distinguished from albite, oligoclase, anorthite, and labradorite. If only a trace of potash is present, the silicate should be heated with ammonium fluoride in a platinum dish, and the residue placed in a flame with a platinum wire.

190. Sodium. The yellow line, Naα, is the only one which appears in the sodium spectrum as seen in the flame with the ordinary spectroscope. With powerful instruments it is seen to be double. The line α is remarkable for its definite form and brightness, and is produced by all the natural compounds of sodium.

191. Lithium. The salts of this metal give a bright line in the red, Liα, and another much less distinct in the orange, Liβ. With high heat and strong prisms a blue line also appears. All lithium compounds give the reaction, and often only require to be held in the flame, as lepidolite, petalite, etc. If the amount is very small in the silicate, it should be digested and evaporated with ammonium fluoride, a little sulphuric acid added, again evaporated, and the residue treated with alcohol. The solution in alcohol is evaporated to dryness, the mass again treated with alcohol, and the liquid dried in a glass capsule. The crust formed can be placed in the flame with a platinum wire.

192. Strontium. The spectra of the alkaline earths are more complex than those of the alkalies. Strontium gives eight very distinct lines—six red, one orange, one blue. The orange line, Srα, close to the sodium line, the two red lines, Srβ and γ, and the blue line, Srδ, are the most

important. The chloride gives the best reaction, while the non-volatile compounds give none. The sulphate must be reduced to sulphide by holding the bead in the reducing flame, and the silicates must be fused with sodium carbonate, powdered, and washed with water by decantation. The insoluble carbonate thus obtained is moistened with hydrochloric acid, and will then give a distinct reaction. The strontium lines do not interfere with the indications of the alkalies.

193. Calcium. The spectrum of this metal is easily distinguished from all the foregoing by the green line, Caβ, and by the orange, Caα. A feeble line is also seen in the violet with a powerful instrument, and other lines with increased heat. The chloride gives the best reaction. The non-volatile compounds must be decomposed by hydrochloric acid and the silicates by ammonium fluoride. The composition of calcareous rocks and minerals is easily found.

194. Barium. The complicated spectrum of this metal is distinguished by its green bands, of which Baα and β are the most important. The haloid salts and more common natural compounds are recognized by holding them in the flame. The silicates must first be treated with hydrochloric acid or fused with sodium carbonate, and then dissolved in acid. If barium and strontium occur in small quantities with calcium, the carbonates obtained by fusion are dissolved in nitric acid and the dried salt exhausted with alcohol. The residue contains only barium and strontium, which can generally be detected.

195. Rubidium. The continuous spectrum is not so extended as that of potassium. The α and β are most brilliant and best suited for the recognition of the metal. The lines δ and γ are less intense, but still very character-

istic. These lines, and even others, appear with not only the volatile chloride, nitrate, etc., but even with the silicates.

196. Cæsium. The spectrum is characterized by two lines, Csα and Csβ, both brilliant and well defined. The absence of any line in the red distinguishes this from the two previous spectra. With an intense light, yellow and green lines may be seen in the continuous parts of the spectrum. Rubidium and cæsium can be easily separated from lithium and sodium by means of platinic chloride, but potassium is precipitated with them, and must be removed by repeated boiling with water before the presence of these two elements can be proved by spectrum analysis.

197. Thallium. The compounds of this metal give a spectrum with a single intense green line, Tlα, which almost coincides with the δ line of barium. Mere traces of thallium in pyrites may be easily detected by simply heating them in the edge of the flame.

198. Indium. The spectrum is characterized by two lines, Inα in the indigo, and Inβ in the violet. The former is far the most intense, and sufficient for the detection of the metal. To show its presence in sphalerite (zinc blende), the mineral is roasted, decomposed by hydrochloric acid, and the solution diluted and saturated with ammonium hydrate. The precipitate containing the indium oxide is dried, and a small portion of it moistened with hydrochloric acid and placed in the flame with platinum wire. The presence of indium will be indicated by the blue line α.

199. It is not only those bodies which have the power of giving color to the flame which yield characteristic spectra, for this property belongs to all elementary sub-

stances, whether metal or non-metal, solid, liquid, or gas; and it is always noticed when such element is heated to the point at which its vapor becomes luminous, for then each element emits the peculiar light given off by it alone, and the characteristic bright lines become apparent when its spectrum is observed. Most metals require a much higher temperature than the common flame, in order that their vapors should become luminous; but they may be easily heated to the requisite temperature by means of the electric spark, which in passing between two points of the metal in question, volatilizes a small portion, and heats it so intensely as to enable it to give off its peculiar light.

Thus all the metals—iron, platinum, silver, gold, etc. —may each be recognized by the peculiar bright lines which its spectrum exhibits.

The permanent gases also yield characteristic spectra, as hydrogen, nitrogen, oxygen, chlorine, carbon dioxide, etc.

By placing gases, solutions of salts, etc. in glass vessels made for the purpose, and placing them between the illuminating flame and the slit in the tube, so that the light will pass through the gas or liquid, the so-called spectra from absorption are obtained. By this arrangement large portions of the complete spectrum disappear through absorption of corresponding rays of light, or else only dark lines are seen in different parts of the same.

For a description of the great number of spectra which have already been carefully studied and mapped, reference must be made to the large works on this subject.

CHAPTER V.

SYSTEMATIC METHODS FOR THE DETERMINATION OF INORGANIC COMPOUNDS.

The careful observer, having become well acquainted with the reactions which are exhibited by the metallic oxides and other simple compounds when subjected to the various treatments detailed in the second chapter, will find no difficulty in ascertaining the nature of any mineral substance presented to him for analysis.

If the reactions are not quite distinct, owing to an intermixture with other substances, he may call to his aid the processes laid down in the third chapter, which will enable him in most cases to detect also the nature of the impurities. But in order to obtain satisfactory results in this way, a certain familiarity with all the principal tests is a necessary condition; this once acquired, any further directions are quite superfluous.

Those, however, who have not devoted much time to blowpipe operations, will sometimes experience some difficulty in drawing the correct conclusions from the observed phenomena—a difficulty which is to a great extent obviated by pursuing some methodical course as given in the following schemes.

The first is applicable for all substances, but the second will be found shorter after a little experience in the case of metallic compounds.

SYSTEMATIC METHOD OF EXAMINATION OF COMPOUND SUBSTANCES.

By J. LANDAUER.

Zeitschrift für Analytische Chemie, XVI. 385.

PRELIMINARY EXAMINATION.

A. The substance heated in a matrass or a tube closed at one end.

a. **Gaseous substances given off:**

1. Colorless and odorless.

Water: Water of crystallization; hydrate.

Oxygen: Peroxides, nitrates, chlorates, bromates, and iodates.

Carbon dioxide: Carbonates and oxalates.

Carbon monoxide: Oxalates and formates. (The latter carbonize.)

2. Colorless with odor.

Sulphur dioxide: Sulphites and some sulphates.

Sulphuretted hydrogen: Thiosulphates and some hydrated sulphides.

Ammonia: Some ammonium salts.

3. With color and odor.

Nitrogen tetroxide: Most of the nitrates and nitrites.

Iodine (violet): Some iodides and iodates.

Bromine (brown): Some bromides.

Chlorine (greenish-yellow): Some chlorides.

b. **Sublimate formed:**

1. White sublimate.

Ammonium salts.

Mercurous chloride, sublimes without first fusing.

Mercuric chloride, first fuses.

Antimony oxide, fuses and forms brilliant needles.
Tellurium dioxide, fuses and sublimes to an amorphous mass.
Arsenic trioxide, octahedral crystals without fusion.

2. *Black or gray sublimate.*

Arsenic: Metallic arsenic and many of its compounds (metallic mirror).
Mercury, amalgam, and some compounds of mercury (metallic globules).

3. *Colored sublimates.*

Sulphur, yellowish-brown while hot; yellow when cold.
Antimony sulphide, black while hot; reddish-yellow when cold.
Arsenic sulphide, brownish-red while hot; reddish-yellow when cold.
Mercuric iodide, yellow; when rubbed, becomes red.
Mercuric sulphide, black; by friction, red.
Selenium, reddish to black; powder dark-red.

c. **Change of color**:

Zinc oxide, from white to yellow; when cold, white.
Tin oxide, yellowish-brown; cold, light-yellow.
Lead oxide, brownish-red; cold, yellow.
Bismuth oxide, white to orange; cold, lemon-yellow.
Mercuric oxide, red to black; cold, red (volatile).
Ferric oxide, red to black; cold, red (*not* volatile).
Mercuric iodide, red to yellow; cold, red.
Hydrated salts of cobalt, nickel, iron, and copper.

d. **Fuse**: Alkaline salts.

e. **Carbonize**: Organic substances.

f. **Phosphoresce:** Alkaline earths, earths, zinc and tin oxides.

g. **Decrepitate:** Alkaline chlorates, galenite, and many minerals.

B. The substance heated in an open tube.

(When the reaction is the same as in preceding section it is omitted.)

a. **Gaseous substances given off:**

Sulphur dioxide, with characteristic smell; sulphur and sulphides.

Selenium dioxide, odor of rotten horse-radish; selenium and selenides.

b. **Sublimate formed:**

Arsenic trioxide, very volatile, white sublimate remote from assay; arsenic and arsenides.

Antimony oxide, white fumes, sublimate partially volatile; antimony and its compounds.

Tellurium dioxide, white fumes, sublimate fusing to colorless drops; tellurium and tellurides.

Lead sulphate,
Bismuth sulphate, } white, mostly beneath the assay; compounds of sulphur with lead or bismuth.

C. The substance heated on charcoal.

a. **Fusibility:**

1. *Fusible.* Alkalies and some salts of alkaline earths. Antimony, lead, cadmium, tellurium, bismuth, zinc, tin (all easily fusible).

   Copper, silver, gold (difficultly fusible).

2. *Infusible.* Salts of the earths, of the alkaline earths, and also silica, iron, cobalt, nickel, molybdenum, tungsten, platinum, palladium, iridium, rhodium, and osmium.

b. **Detonation.** Nitrates, chlorates, iodates, bromates.
c. **Intumescence,** giving off water; borates and alum.
d. **Flame-coloration, reduction to metal,** and **formation of coating** are described in special reactions.

COMPLETE EXAMINATION.

DETECTION OF BASES.

The substance is treated on charcoal in the reducing flame with sodium carbonate; or in the case of a metal or alloy, alone.

a. The substance forms a coating, . See Sect. I., 1–9.
b. The substance forms a metallic bead, without coating, . . " " I., 10–12.
c. The substance leaves a gray or black residue, . . . " " II., 13–31.
d. The substance colors the flame, especially when moistened with HCl, ... " " IV., 32–42.
e. The substance leaves a white luminous residue, . . . " " V., 43–51.
f. The substance completely volatilizes, ... " " VI., 52, 53.

(Formation of hepar is indication of a sulphate or a sulphide.)

Section I.

1. *Coating white*, very volatile; disappears with light-blue flame, and characteristic alliaceous odor,

Arsenic.

1* Special Test. Heated with potassium cyanide and soda in a matrass, forms a metallic mirror.

2. *Coating reddish-brown*, with variegated border; volatilized by both flames without coloring them,

Cadmium.

2* Sp. T. The coating, placed in a matrass with sodium thiosulphate, becomes yellow. Compare with No. 3* in presence of zinc.

3. *Coating yellow* while hot; *white* when cold; luminous and is not volatilized, ... **Zinc.**

3* Sp. T. The coating, moistened with cobalt solution and heated, becomes green. In presence of both Cd and Zn the Cd coating appears first, and then the Zn.

4. *Coating steel-gray;* disappears in the reducing flame with azure coloration, and gives off the odor of rotten horse-radish, ... **Selenium.**

4* Sp. T. Compare No. 5*.

5. *Coating white,* with dark-yellow to reddish border; disappears in the reducing flame with green coloration, ... **Tellurium.**

5* Sp. T. If Se and Te are both present, a white coating is formed, the reducing flame is colored bluish-green, and the rotten horse-radish odor given off. For separation, a metallic coating of the two metals is made in a small glass tube, moistened with a drop of H_2SO_4, and *gently* heated. Te dissolves with a carmine-red color, and if *strongly* heated, the dirty-green color of the Se appears.

6. *Coating bluish-white;* volatile; driven about by the oxidizing flame; disappears in the reducing flame with green coloration.

Bead: white, brittle, oxidizable, . **Antimony.**

6* Sp. T. If the coating is placed on platinum foil with a piece of zinc and moistened with HCl, a black adherent coating of antimony is formed on the foil.

7. *Coating orange* while hot; *lemon-yellow* when cold, driven about by both flames without coloring them.

Bead: reddish-white, brittle, oxidizable, **Bismuth.**

7* Sp. T. On charcoal with potassium iodide, and sulphur in the oxidizing flame, give a red coating of bismuth iodide.

8. *Coating lemon-yellow* while hot; *sulphur-yellow* when cold; driven away by the oxidizing and also reducing flame; colors the reducing flame blue.

Bead: gray, malleable, oxidizable, . . **Lead.**

8* Sp. T. Moisten the assay with HNO_3, evaporate the excess of acid, add H_2SO_4, and heat till a white vapor is given off. A white powder remains, wholly insoluble in dilute H_2SO_4.

9. *Coating yellowish* while hot; *white* when cold; very slight, close to the assay, and not volatile.

Bead: white, malleable, and very oxidizable, **Tin.**

9* Sp. Dissolves in HCl, add Zn, which precipitates metallic tin as a gray spongy mass that does not adhere to the platinum like antimony. A crystal of $Na_2S_2O_3$ precipitates brown SnS from the solution to which the Zn has been added.

10. *Bead white*, malleable, brilliant. In strong oxidizing flame, a reddish-brown coating is formed, which in the presence of lead and antimony becomes carmine-red, ... **Silver.**

10* Sp. T. Dissolved in HNO_3, HCl produces a white, curdy precipitate of AgCl.

11. *Bead yellow*, brilliant, malleable, not oxidizable, **Gold.**

11* Sp. T. Dissolved in aqua regia, $SnCl_2$ gives purple of Cassius.

12. *Bead red*, malleable, and oxidizable, . **Copper.**

12* Sp. T. Compare Nos. 13 and 39.

Iron, nickel, cobalt, molybdenum, tungsten, and the platinum group of metals yield a gray infusible powder. Iron, nickel, and cobalt, which are more or less magnetic, may be further tested with borax (Sect. II.), but for the other metals the blowpipe reactions are not as characteristic. Compounds of chromium give a yellow, and of

manganese, a green mass, with sodium carbonate (Section II.).

Some chlorides, iodides, bromides, and sulphides give a white coating, without a complete reduction of the metal, which should not be mistaken for any of the foregoing. These will be recognized in the course of analysis by other and more characteristic tests. Sulphuretted hydrogen, recognized by its odor, indicates a sulphate or sulphide.

Section II. Treated with borax on platinum wire.

a. Colored bead formed in the oxidizing flame and reducing flame, . . Nos. 13–31.

b. Bead not colored, . . Section IV. " 32–38.

THE COLOR OF THE BEAD IS—

In the Oxidizing Flame.		In the Reducing Flame.		
Hot.	Cold.	Hot.	Cold.	
13. Green,	Bluish-green,	Colorless,	Brown,	**Copper.**
14. Blue,	Blue,	Blue,	Blue,	**Cobalt.**
15. Violet to black,	Reddish-violet,	Colorless,	Colorless to pink,	**Manganese.**

13* Sp. T. With salt of phosphorus and reduced with Sn, it becomes red; if it turns black it should be heated on charcoal, and the Sb and Bi separated with boric acid in the oxidizing flame.

14* Sp. T. The metal, reduced on charcoal and placed upon paper, gives, with HNO_3, a red solution, which, with HCl added, and drying, gives a green spot, which disappears when moistened with water.

15* Sp. T. Fused with sodium carbonate and nitrate, forms a green mass.

In the Oxidizing Flame.		In the Reducing Flame.		
Hot.	Cold.	Hot.	Cold.	
16. Violet,	Reddish-brown,	Yellowish-gray,	Yellowish-gray,	**Nickel.**
17. Red, in small quantity.	Colorless,	Green,	Bottle-green,	**Iron.**
18. Do.	Colorless,	Green,	Bottle-green,	**Uranium.**
19. Do.	Colorless, in excess opalescent,	Brown,	Brown (cloudy),	**Molybdenum.**
20. Do.	Grass-green,	Green,	Emerald-green,	**Chromium.**
21. Do.	Colorless, in excess yellow,	Colorless,	Colorless,	**Cerium.**
22. Do.	Greenish-yellow,	Brownish,	Emerald-green,	**Vanadium.**
23. Do.	Colorless, in excess enamel-white,	Yellow,	Yellowish-brown,	**Tungsten.**
24. Do.	Colorless,	Yellow to brown,	Yellow to brown, by flaming, blue,	**Titanium.**

16* Sp. T. The metal, reduced on coal and placed upon paper, gives, with HNO_3, a green solution, which, touched with Na_2CO_3, produces an apple-green spot.

17* Sp. T. The metal, reduced on coal and placed upon paper, moistened with HNO_3 and HCl, and warmed over the gas flame, gives a yellow spot, which turns blue when moistened with potassium ferrocyanide.

18* Sp. T. The salt of phosphorus bead in the oxidizing flame is yellow while hot and yellowish-green when cold; in the reducing flame it is a dirty-green while hot, clear bright-green when cold, and thus differs from iron.

The insoluble compounds of uranium are fused with $HKSO_4$, rubbed or ground with Na_2CO_3, moistened, and absorbed by paper. The spot is then moistened

with acetic acid and potassium ferrocyanide, which produces a brown color.

19* Sp. T. Digested with H_2SO_4 on the platinum spoon, MoO_3 turns deep-blue if a little alcohol is added, or if it is breathed upon.

20* Sp. T. Fused with soda and nitre on platinum, forms a yellow mass.

21* Blowpipe reactions are not decisive tests.

22* Sp. T. Fused with soda and nitre, dissolved in water, acetic acid added, $AgNO_3$ gives a yellow precipitate.

23* Sp. T. The salt of phosphorus bead in the oxidizing flame is colorless both when hot and cold; in the reducing flame, dirty-green while hot, blue when cold, and blood-red on the addition of iron. Compare No. 27.

24* Sp. T. The salt of phosphorus bead is colorless in the oxidizing flame, both when hot and cold; in the reducing flame, yellow while hot, violet when cold, and blood-red on the addition of iron. Compare No. 30.

25. Color of the bead when more than one of the oxides is present.

In the Oxidizing Flame.		In the Reducing Flame.		
Hot.	Cold.	Hot.	Cold.	
Violet to blood-red,	Brownish-violet,	Yellow,	Bottle-green,	Fe and Mn.
Plum color,	Plum color,	Bluish-green,	Blue,	Fe, Mn, Co.
Green,	Grayish-blue,	Bluish-green,	Green,	Fe, Mn, Co, Ni.
Yellowish-green,	Green,	Greenish-blue,	Blue,	Fe, Co, little Ni.
Violet-brown,	Brown,	Blue,	Blue,	Co and much Ni.
Green,	Green, blue, or yellow, according to saturation,	. . . . .		Fe and Co. Fe and Cu. Fe and Ni.

25* Sp. T. A number of beads are made by fusing the substances with borax on platinum wire, and then reducing on charcoal with the addition of a globule of lead. After blowing for some time, the bead (A) is separated from the lead globule (B) and examined.

A. The *Bead* or fragments are fused with borax on platinum wire:

a. The bead is blue, ... **Cobalt.**

b. The bead is green while hot; blue when cold in the oxidizing flame, ... **Iron and cobalt.**

c. The bead is violet to blood-red while hot, and brownish-violet when cold in the oxidizing flame; yellow while hot, bottle-green when cold in reducing flame; on charcoal reduced with tin, vitriol-green. With insufficient oxidizing flame the bead is yellow while hot, colorless when cold, . . **Manganese and iron.**

d. The bead is plum color in the oxidizing flame, both when hot and cold; in the reducing flame, bluish-green while hot, and blue when cold,

Manganese, iron, and cobalt.

B. *The lead globule* is treated with boric acid on charcoal in the oxidizing flame to separate the lead, and the residue fused with salt of phosphorus:

a. The bead is blue when cold in the oxidizing flame, but reduced with Sn on charcoal, becomes red, **Copper.**

b. The bead is yellow when cold in oxidizing flame, **Nickel.**

c. The bead is green when cold in oxidizing flame, **Copper and nickel.**

Section III. The substance is fused with acid potassium sulphate, dissolved in hydrochloric acid, and a strip of zinc added.

(This section is passed by when tungsten, vanadium, titanium, and niobium are absent.)

The solution becomes—

26. Blue, then green, finally dark-brown, **Molybdic acid.**

26* Sp. T. See No. 19.

27. Blue, then copper-red, . . **Tungstic acid.**

27* Sp. T. See No. 23.

28. Blue, then green, finally violet, . **Vanadic acid.**

28* Sp. T. See No. 22.

29. Green, ... **Chromic acid.**

29* Sp. T. See No. 20.

30. Violet, ... **Titanic acid.**

30* Sp. T. See No. 24.

31. Blue, or in strongly acid solutions, brown, **Niobic acid.**

Section IV. The substance is placed in the non-luminous flame, with the platinum forceps or wire.

a. The flame is colored, especially if the substance is moistened with HCl or H_2SO_4, . Nos. 32–42.

b. The flame is not colored, Section V., Nos. 43–51.

Examination for Bases.

The color of the flame appears—

	Alone.	Through Blue Glass.	Through Green Glass.		
Moistened with H_2SO_4, and held for a short time only in the flame.	**32.** Violet.	Reddish-violet.	Bluish-green.	**Potassium.**	Ba, Ca, and Sr can be recognized when together, if moistened with HCl and the flashes of color in the flame carefully noticed.
	33. Orange.	Reddish-violet.	Orange-yellow.	**Potassium and sodium.**	
	34. Orange.	Invisible or pale-blue.	Orange-yellow.	**Sodium.**	
	35. Carmine.	Violet-red.	Invisible.	**Lithium.**	
Repeatedly moistened with H_2SO_4, dried, and intensely heated.	**36.** Yellowish-green.	Bluish-green.	Green.	**Barium.**	
	37. Yellowish-red.	Greenish-gray.	Celery-green.	**Calcium.**	
	38. Carmine.	Purple.	Pale-yellow.	**Strontium.**	

39. Green, moistened with HCl, blue, . . **Copper.**

EXAMINATION FOR ACIDS.

40. Yellowish-green, similar to barium flame, **Molybdic acid.**

40* Sp. T. Gives with borax the reactions of No. 19.

41. Yellowish-green (salts moistened with H_2SO_4), **Phosphoric acid.**

41* Sp. T. Heated with a piece of Mg wire, or of Na, in the closed tube, the mass, moistened with H_2O, gives the smell of phosphoretted hydrogen.

42. Green (salts moistened with H_2SO_4), **Boric acid.**

42* Sp. T. With $CaFl_2$ and $HKSO_4$, heated on platinum, gives the intense green flame of boron fluoride.

REMARKS.—Chlorides and nitrates give green flashes, but very weak, and quickly disappear.

The flame-colors of As, Sb, Pb (blue), Zn (greenish-white), are for the most part obscured by the use of concentrated H_2SO_4.

Section V. The substance is placed on charcoal, moistened with cobalt solution, and strongly heated.

43. Blue, infusible mass, ... **Alumina.**

43 Sp. T. With No. 41, no coloration; also no silica skeleton is formed in the salt of phosphorus bead.

44. Blue, infusible mass, . . **Earthy phosphates.**

44* Sp. T. In No. 41, yellowish-green flames.

45. Blue, infusible mass, . . **Earthy silicates.**

45* Sp. T. In salt of phosphorus bead, forms a silica skeleton.

46. Blue glass, ... **Alkaline borates.**

46 Sp. T. With No. 42 shows a bright-green flame.

47. Blue glass, . . . **Alkaline phosphates.**

47 Sp. T. With No. 41 shows a yellowish-green flame.

48. Blue glass, ... **Alkaline silicates.**

48* Sp. T. In the salt of phosphorus bead forms a skeleton of silica.

49. Flesh-red mass, ... **Magnesia.**

50. Violet mass, ... **Zirconia.**

51. Green mass, . . **Oxides of** { Zinc, Tin, Antimony, Titanium.

Section VI. The substance heated in a closed tube with soda.

52. Metallic sublimate; may be collected into small globules, ... **Mercury.**

52* Sp. T. Heated in the closed tube with $Na_2S_2O_3$, forms black HgS.

53. Smell of ammonia, ... **Ammonia.**

53* Sp. T. With HCl forms a white cloud.

DETECTION OF ACIDS.

Section VII. The substance heated in a closed tube with acid potassium sulphate.

a. Gives off a colored gas, . . . Nos. 54–59.

b. " " colorless, pungent gas, . " 60–67.

c. " " " and inodorous gas, " 68–70.

d. " no reaction, . Section VIII., " 71.

54. Red vapor, with smell of nitrogen tetroxide, **Nitrous or nitric acid.**

54* Sp. T. Paper, moistened with solution of ferrous sulphate, acidulated with sulphuric acid, placed in the tube, is colored brown; nitrates, heated on platinum foil with potassium cyanide, detonate and burn.

55. Yellowish-green gas, with smell of chlorine, **Chloric acid.**

55* Sp. T. Detonates on charcoal.

56. Violet vapor; colors starch-paste blue, . **Iodine.**

56* Sp. T. A salt of phosphorus bead, with copper oxide and an iodide compound, gives a clear-green flame.

57. Same as 56; with the addition of ferrous sulphate, indicates . . . . . **Iodic acid.**

57* Sp. T. The substance detonates on charcoal.

58. Reddish-brown vapor; colors starch-paste yellow, **Bromine.**

58* Sp. T. A salt of phosphorus bead, with copper oxide and compound of bromine, colors the flame greenish-blue.

59. The same reactions, . . . **Bromic acid.**

59* Sp. T. The substance detonates on charcoal.

60. Vapors, which form with NH_3 a white cloud, and have the odor of . . **Hydrochloric acid.**

60* Sp. T. A salt of phosphorus bead, with copper oxide and compound of chlorine, colors the flame intense blue.

61. Strongly-fuming gas, which etches glass, **Hydrofluoric acid.**

62. Smell of **sulphuretted hydrogen,** **Hydrosulphuric acid.**

62* Sp. T. Metallic sulphides, heated in the open tube, give off sulphur dioxide fumes, which may be known by the smell and action upon moist blue litmus-paper.

63. Smell of burning sulphur; no separation of sulphur, **Sulphur dioxide.**

64. Same reaction, with separation of sulphur, **Thiosulphuric acid.**

65. Pungent gas; irritates the eyes to tears, and renders lime-water turbid, . . . **Cyanic acid.**

66. Smell of vinegar, ... **Acetic acid.**

67. Smell of prussic acid, . . **Hydrocyanic acid.**

68. The gas effervesces and causes turbidity in lime-water, ... **Carbon dioxide.**

69. The gas burns with a blue flame, **Carbon monoxide.**

70. Carbonization, . . . **Organic acids.**

REMARK.—Some few organic acids do not carbonize—*i. e.*, oxalic, formic, etc.

Section VIII. A substance which indicates a sulphide with soda on coal is heated in a platinum spoon with caustic potash, and the whole placed in a vessel with water, and a bright silver coin laid upon it.

71. The coin is not blackened, . **Sulphuric acid.**

71* Sp. T. In order to distinguish sulphates from sulphides (No. 62), the substance is dissolved in water acidified with nitric acid, and the sulphuric acid is thrown down with barium chloride.

Insoluble sulphates are first boiled in solution of sodium carbonate, then filtered, and decomposed with nitric acid.

Section IX. Already found in the course of analysis:

72. **Phosphoric acid** (No. 41), **boric acid** (No. 42), **silicic acid** (No. 45).

II. SYSTEMATIC METHOD OF EXAMINATION OF COMPOUND SUBSTANCES.

By Prof. T. EGLESTON.
American Chemist, 1872.

The substance may contain As, Sb, S, Se, Fe, Mn, Cu, Co, Ni, Pb, Bi, Ag, Au, Hg, Zn, Cd, Sn, Cl, Br, I, CO_2, SiO_2, HNO_3, H_2O, etc.

Treat on charcoal in the oxidizing flame to find volatile substances, such as As, Sb, S, Se, Pb, Bi, Cd, etc. (par. 25, *et seq.*).

Volatile substances not present.

Divide a part of the substance into three portions and proceed as in **A.**

Volatile substances present.

(1) Form a coating on charcoal and test with salt of phosphorus and tin for antimony (par. 65), or separate lead and bismuth, as in pars. 64, 74.

a. Yellow coating, yielding, with salt of phosphorus, a black bead; disappearing with blue flame, no part of it yielding green Sb. flame; **Pb, Bi.**

b. Yellow coating, generally with white border, yielding black or gray bead with salt of phosphorus; disappearing with blue flame; also the border disappearing with green flame; **Pb, Sb.**

c. Yellow coating, very similar to *b*, but yielding no blue flame; **Bi, Sb.**

(2) If **As, Sb, S, Se** are present, roast a large quantity thoroughly on charcoal until no odor of arsenic or sulphur dioxide is given off. Divide the substance into three portions, and proceed as in **A.**

A. Treatment of the first portion.

Dissolve a small quantity in borax on platinum wire in the oxidizing flame, and note the color. When several oxides are present, successive colors often appear; in this case, saturate the bead and toss it off into a porcelain dish (par. 3 and page 54). Prepare several beads in this way, and treat them on charcoal with metallic lead, silver, or gold in a strong reducing flame (pars. 87, 89). If the mass spreads over the charcoal, continue blowing until a bead is formed.

The *metallic bead* (*a*) is removed from the *borax residue* (*b*) whilst hot, or with a hammer when cold, all fragments being carefully preserved.

a. The *metallic bead* contains the reduced Ni, Cu, Ag, Au, Sn, Pb, and Bi (Sn, Pb, and Bi are partially volatilized).

Treat this bead on charcoal in the oxidizing flame until all the Pb is removed, or remove the Pb with boric acid (par. 88). Ni, Co, Ag, Au remain behind.

Treat this residue on charcoal (oxidizing flame) with salt of phosphorus, and remove the bead whilst hot:

A green bead when cold indicates (par. 89) **Ni** and **Cu**, yellow **Ni**, blue **Cu**.

The Cu bead, heated on charcoal (reducing flame) with metallic tin, becomes red (par. 88).

The presence of **Ag** and **Au** is ascertained by special examination.

b. The *borax residue* retains the Fe, Mn, Co, etc.

Dissolve a fragment of the bead in borax on the platinum wire; a blue bead indicates, **Co.**

In presence of much iron add more borax to detect the Co (pars. 86, 87).

Dark-violet or black bead in oxidizing flame, **Mn.**

When only Fe and Mn are present, an almost colorless bead (reducing flame) results.

Test in the wet way (par. 51) for **Cr, Ti, Mo, Nb, W, V.**

B. Treatment of the second portion.

Heat on charcoal in the reducing flame with Na_2CO_3, and look for indications of **Zn, Cd,** and **Sn.** If a white coating results, treat with cobalt solution (par. 60).

C. Treatment of the third portion.

Dissolve in salt of phosphorus on platinum wire (oxidizing flame) for SiO_2, and test for **Mn** with KNO_3 (par. 104).

Special tests.

1. To confirm **As,** heat on charcoal with Na_2CO_3, or in closed tube with *dry* Na_2CO_3 (par. 69, *et seq.*).

2. Dissolve in salt of phosphorus on platinum wire in the oxidizing flame (provided the assay is neither a metal nor contains S), and test for **Sb** on charcoal with metallic tin in reducing flame (par. 65).

3. Test for **Se** on charcoal (par. 113).

4. In absence of Se, fuse with Na_2CO_3 (reducing flame), and test for **S** on silver foil (par. 121). If **Se** be present, test for **S** in an open tube (par. 20). To distinguish between sulphides and sulphates see par. 104.

5. Test for **Hg** by heating in closed tube with *dry* Na_2CO_3 (par. 11).

6. Fuse with assay-lead and borax-glass on charcoal in reducing flame. Cupel the Pb bead for **Ag** (par. 117). Test for **Au** by means of HNO_3 (par. 95).

7. Test for **Cl, Br,** and **I** with salt of phosphorus bead containing Cu (pars. 82, 97).

8. Test **Cl** and **Br** with $HKSO_4$ (par. 79).
9. Test for water in closed tube (par. 9).
10. Apply flame-coloration tests (par. 57–61).
11. Test for CO_2 with HCl.
12. Test for HNO_3 by means of $HKSO_4$ (par. 106).
13. Test for **Te** according to par. 122.

When sulphides, etc. are under examination, they must be well roasted; but if S, As, Sb, or Se, as sulphides, etc., are absent, the substance is either an oxide or an alloy. If an oxide, the roasting is unnecessary; if an alloy, it is tested by (1) *a* for Pb, etc., and then the test is made by fusing the substance on charcoal with borax in the reducing flame, thus performing in the same operation the test A and A, *a*. Some sulphides during roasting (A) are reduced, and are then treated like alloys. Metals, sulphides, etc. should be fused on charcoal with the flux, and not on platinum. The reducing flame is used if only the non-reducible metals, as Fe, Co, etc., are to be obtained in the flux; the oxidizing, if Cu, Ni, etc., and other reducible metals. The flux may then be taken up on the wire. Sulphides, etc. must always be roasted before testing with borax and salt of phosphorus.

In B, Sn can always be found in the presence of Zn by reducing the oxides with soda and a little borax, and triturating the mass in water (par. 46). In some alloys, for example, bronzes, containing both Sn and Zn, the latter can be detected by treating a short time in the reducing flame, and testing the coating formed with cobalt solution, as the Zn coating forms first.

The word *button* refers to the metal, and *bead* to the flux.

TABLES

SHOWING THE BEHAVIOR OF THE ALKALIES,
EARTHS, AND METALLIC OXIDES, ALONE,
AND WITH REAGENTS, BEFORE
THE BLOW-PIPE.

TABLE I.—Behavior of the alkalies and alkaline earths before the blowpipe.

Alkalies.	*Alone on Platinum Wire.*
1. POTASH. K_2O.	Colors the flame violet; but even a minute quantity of soda obscures the reaction. See par. 58.
2. SODA. Na_2O.	Colors the flame intense reddish-yellow, even in the presence of a large excess of potash.
3. LITHIA. Li_2O.	Colors the flame carmine-red, even in the presence of potash; but soda gives a yellowish-red. See par. 59.
4. AMMONIA. NH_3.	Combined with chlorine, nitric or sulphuric acids, it colors the flame very pale-green.

TABLE I.— Continued.

Alone on Platinum Foil.	*Remarks.*
No change.	In solution, change red litmus paper to blue.
No change.	Same as Potash.
Turns the foil yellow when fused; but if washed and ignited the color is destroyed, but the foil remains dull.	Same as Potash.
No reaction.	Pungent odor, colors red litmus paper blue.

TABLE I.—Continued.

Alkaline Earths.	*On Charcoal alone, and in the forceps.*	*With Sodium Carbonate on Charcoal.*
5. BARYTA. BaO.	The Hydrate fuses, boils, intumesces, and is finally absorbed by the charcoal. The Carbonate fuses readily to a transparent glass, which, on cooling, becomes enamel-white. In the forceps it colors the outer flame yellowish-green.	Fuses to a homogeneous mass, which is absorbed by the charcoal.
6. STRONTIA. SrO.	The Hydrate behaves like Barium hydrate. The Carbonate fuses only on the edges, and swells out in arborescent ramifications, which emit a brilliant light, and, when heated with the R. F., impart to it a reddish tinge; shows after cooling alkaline reaction. In the forceps, colors the outer flame crimson.	Caustic Strontia is insoluble. The Carbonate, mixed with its own volume of soda, fuses into a limpid glass, which becomes enamel-white on cooling. At a greater heat the mass boils, and caustic Strontia is formed, which is absorbed by the charcoal.
7. LIME. CaO.	Caustic Lime is not changed. The Carbonate loses carbon dioxide, becomes whiter and more luminous, and shows after cooling alkaline reaction. In the forceps it colors the outer flame pale-red.	Insoluble. The soda passes into the charcoal, and leaves the lime unaltered on its surface.
8. MAGNESIA. MgO.	Undergoes no alteration. The Carbonate becomes caustic and luminous. On addition of cobalt solution and flaming becomes pink.	It behaves like lime.
9. ALUMINA. Al_2O_3.	Not changed. On addition of cobalt solution and flaming becomes blue.	Forms an infusible compound, with slight intumescence. The excess of soda is absorbed by the charcoal.

TABLE I.—Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
The Carbonate dissolves with effervescence to a limpid glass which, with a certain amount, becomes opaque by flaming; with more, it becomes opaque-white on cooling, even without flaming.	As with Borax.
Same as Baryta.	Same as Baryta.
Readily dissolved to a limpid glass, which becomes opaque by flaming. The Carbonate dissolves with effervescence. On a large addition of Lime the glass becomes cloudy and crystallizes on cooling, but does not become enamel-white, like Baryta or Strontia.	Soluble in large quantities to a limpid glass which, when sufficient Lime is present, becomes opaque by flaming. When saturated, the glass becomes enamel-white on cooling.
It behaves like lime, but not so crystalline.	Readily soluble to a limpid glass, which becomes opaque by flaming. When saturated, it becomes, on cooling, enamel-white.
Dissolves slowly to a limpid glass, which remains so on cooling, and which cannot be made cloudy by flaming. A large quantity of alumina makes the glass cloudy and nearly infusible; on cooling, it then assumes a crystalline surface, and is scarcely fusible.	Soluble to a limpid glass, which remains clear under all circumstances. If too much alumina be added, the undissolved portion becomes translucent.

TABLE I.—Continued.

Alkaline Earths.	*On Charcoal alone, and in the forceps.*	*With Sodium Carbonate on Charcoal.*
10. GLUCINA. BeO.	Not changed. With cobalt solution and flaming turns bluish-gray.	Insoluble.
11. YTTRIA. YO.	Not changed.	Insoluble.
12. ZIRCONIA. Zr^2O^3.	Infusible, but emitting a very glaring light.	Insoluble.
13. ERBIA. EO.	The yellow oxide becomes lighter-colored and transparent in the R. F.	Insoluble.
14. THORIA. ThO.	Not changed.	Insoluble.
15. SILICA. SiO_2.	Not changed. On addition of cobalt solution and flaming becomes pale-blue. If slightly fused the color is deeper.	Soluble, with effervescence, to a clear glass.

TABLE I.— Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
Soluble in large quantities to a limpid glass, which becomes opaque by flaming. When Glucina is present in excess, it becomes enamel-white on cooling.	As with Borax.
Like Glucina.	Like Glucina.
Like Glucina.	Dissolves more slowly than with Borax.
Dissolves slowly to a clear glass, which becomes opaque by flaming, or on cooling if in excess.	As with Borax.
In small quantity dissolves to a clear glass, which becomes enamel-white on cooling if in excess; if clear, it cannot be made opaque by flaming.	As with Borax.
Dissolves slowly to a limpid glass, difficultly fusible, and cannot be made opaque by flaming.	Soluble in very small quantities to a limpid glass. The insoluble portion, or silica skeleton, floats about as a translucent mass in the clear glass.

TABLE II.—Behavior of the metallic oxides before the blowpipe.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
1. ANTIMONY TRIOXIDE. Sb_2O_3.	O. F.: It is displaced and deposited upon another part of the charcoal. R. F.: It is reduced and volatilized. A coating of oxide is deposited on the charcoal, and a greenish-blue color imparted to the flame.	On charcoal very readily reduced in O. F. and R. F. The metal fumes and coats the charcoal with antimony oxide.
2. ARSENIC TRIOXIDE. As_2O_3.	Volatilizes below a red heat.	On charcoal reduced, with emission of arsenical fumes, which are characterized by a strong garlic odor.
3. BISMUTH TRIOXIDE. Bi_2O_3.	O. F.: On platinum foil it fuses readily to a dark-brown mass, which, on cooling, becomes pale-yellow. On charcoal in O. F. and R. F. reduced to metallic bismuth, which, with long blowing, vaporizes, coating the charcoal with yellow oxide. The coating, when touched with the R. F., disappears without coloring the flame.	Easily reduced to metallic bismuth.
4. CADMIUM OXIDE. CdO.	O. F.: On platinum foil unchanged. R. F.: On charcoal it disappears in a short time, and deposits all over the charcoal a dark-yellow or reddish-brown powder. The outer part of the coating is also iridescent.	O. F.: Insoluble. R. F.: On charcoal readily reduced; the metal vaporizes and deposits a dark-yellow or reddish-brown coating on the charcoal. The more remote portion of the coal assumes a variegated appearance.

TABLE II. — Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F. : Dissolves in large quantities to a limpid glass, which, while hot, appears yellowish, but after cooling, colorless. R. F. : The glass, when treated only for a short time in the O. F., becomes on Ch. grayish and cloudy from particles of reduced antimony. With tin it becomes gray or black, according to the degree of saturation.	O. F. : Dissolves with effervescence to a limpid glass, which, while hot, is slightly yellowish. R. F. : On Ch. the saturated bead becomes at first cloudy, but afterwards clear again, owing to the volatilization of the reduced antimony. Treated with tin, the glass becomes, after cooling, gray, even if but very little antimony trioxide is present. With strong blowing it becomes clear again.
O. F. : A small quantity is easily dissolved to a clear yellow glass, which, on cooling, becomes colorless. On a large addition of oxide, the glass, while hot, is yellowish-red, becomes yellow on cooling, and when cold is opalescent. R. F. : On Ch. the glass becomes at first gray and cloudy, the oxide is reduced to metal with effervescence, and the bead becomes clear again. An addition of tin accelerates the process.	O. F. : Readily dissolved to a limpid yellow glass, which, on cooling, becomes colorless. When a greater quantity of oxide is present, the glass may be made enamel-white by flaming, and on a still larger addition it becomes by itself enamel-white on cooling. R. F. : On Ch., particularly when tin is added, the glass remains colorless and limpid while hot, but becomes, on cooling, dark-gray and opaque.
O. F. : Soluble in large quantity to a limpid yellowish glass, becoming almost colorless on cooling. When highly saturated, it may be made enamel-white by flaming, and when still more oxide is present, it becomes by itself enamel-white on cooling. R. F. : Placed on Ch., it enters into ebullition; the oxide is reduced; the reduced metal vaporizes immediately and deposits a dark-yellow coating.	O. F. : Soluble in large quantity to a limpid glass, which, while hot, is yellowish, but colorless when cold; when saturated, it becomes enamel-white on cooling. R. F_2 : On Ch., the oxide becomes slowly and imperfectly reduced. The reduced metal deposits a very feeble Ct. of dark-yellow color. The color is only clearly seen when the mass is cold. An addition of tin facilitates the reduction.

TABLE II. — Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
5. CERIUM SESQUIOXIDE. Ce_2O_3.	The protoxide is converted into sesquioxide, Ce^2O^3 by the O. F., which remains unaltered in the R. F.	Insoluble. The soda passes into the charcoal; the sesquioxide is reduced to protoxide, which remains on the charcoal as as a light-gray powder.
6. CHROMIUM SESQUIOXIDE. Cr_2O_3.	Not changed in the O. F. or R. F.	O. F. : On platinum wire soluble to a dark yellowish-brown glass, which on cooling becomes opaque and yellow. (Chromic acid.) R. F. : The glass becomes opaque and green on cooling. On charcoal it cannot be reduced to metal; the soda passes into the charcoal, and the oxide remains behind as a green powder, Cr_2O_3.
7. COBALT MONOXIDE. CoO.	O. F.: Not changed. R. F.: It is reduced to metal, but does not fuse: the mass is attracted by the magnet, and assumes metallic lustre by friction.	O. F.: On platinum wire a very small quantity is dissolved to a transparent mass of a pale-reddish color, which, on cooling, becomes gray. R. F.: On charcoal reduced to a gray magnetic powder, which becomes lustrous by rubbing.

TABLE II. — Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F. : Soluble to a limpid glass of dark-yellow or red color, which changes on cooling to yellow. When highly saturated with oxide the glass becomes, on cooling, enamel-white. R.F. : The yellow glass becomes colorless. A highly saturated bead becomes on cooling enamel-white and crystalline.	O. F.: As with borax, but on cooling, colorless. R. F.: Perfectly colorless, hot and cold, thus being distinguished from an iron sesquioxide glass. Never becomes opaque on cooling, however large the amount of oxide present.
O. F. : Dissolves but slowly, but colors intensively. If little of the oxide is present, the glass, while hot, is yellow; when cold, yellowish-green; with more oxide it is dark-red while hot, becomes yellow on cooling, and when perfectly cold has a fine yellowish-green color. R. F. : The glass is green, hot and cold. The intensity of the color depends on the amount of oxide present. Tin causes no change.	O. F.: Soluble to a limpid glass, which, while hot, appears reddish; when cold it has a fine green color. R. F.: As in O. F., but the colors are more intense. The same on addition of tin.
O. F.: Colors very intensively. The glass appears pure smalt-blue, hot and cold. An excess of oxide imparts to the bead a deep bluish-black color. R. F. : As in O. F.	O. F.: As with borax, but for the same quantity of oxide the color is not quite so deep. R. F.: As in O. F.

TABLE II.—Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
8. COPPER OXIDE. CuO.	O. F.: Fuses to a black globule, which becomes reduced where it is in contact with the charcoal. R. F.: Reduced to metal at a temperature below the melting-point of copper. When the heat is increased, a globule of metallic copper is obtained.	O. F.: On platinum wire soluble to a limpid glass of green color; on cooling it becomes opaque and white. R. F.: On charcoal easily reduced to metal, which, when the temperature is sufficiently high, fuses to one or more globules.
9. DIDYMIUM OXIDE. D_2O_3.	Unaltered.	Insoluble. The soda is absorbed by the coal, and the gray oxide remains behind.
10. GOLD TRIOXIDE. Au_2O_3.	When heated to ignition it becomes reduced to metal in O. F. and R. F. The metal fuses easily to a globule.	Does not dissolve in the soda, but is easily reduced in both flames. The metal fuses readily to a globule. The soda passes into the charcoal.
11. INDIUM OXIDE. In_2O_3.	In the O. F. becomes dark-yellow when heated, but on cooling is again lighter, and does not fuse. In the R. F. is gradually reduced and volatilized, depositing a coat on the coal. A distinct violet flame is produced.	In the O. F. insoluble. In the R. F. is reduced on coal, and the metal partly volatilizes, coating the coal with oxide, while a portion may be seen as almost silver-white globules in the fused salt.
12. IRIDIUM DIOXIDE. IrO_2.	At a red heat becomes reduced; the reduced metal is infusible.	O. F.: Does not dissolve in the soda, but becomes reduced; the metal cannot be fused to a globule. R. F.: As in O. F.

TABLE II. — Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F. : A small addition of oxide makes the glass appear green while hot, but blue when cold. A large quantity imparts to it a very deep-green color while hot, becoming greenish-blue when cold. R. F. : A glass containing a certain quantity of oxide becomes colorless, but on cooling becomes opaque and red (suboxide). On Ch. the copper may be precipitated in the metallic state, the bead becoming in consequence colorless. A glass containing protoxide, when treated on Ch. with tin, becomes on cooling brownish-red and opaque.	O. F. : As with borax, but for the same amount of oxide the coloration is not so deep. R. F. : A glass containing a large quantity of oxide becomes dark-green, which in the moment of refrigeration changes suddenly to brownish-red and opaque. A glass containing but little oxide, when treated on Ch. with tin, appears colorless while hot, but becomes brownish-red and opaque on cooling.
In the O. F. soluble to a clear colorless glass, and remains unaltered in the R. F. When strongly saturated, becomes rose-color.	Dissolves with more difficulty than in borax, but when strongly saturated is distinctly rose-red in the R. F.
As with sodium carbonate.	As with sodium carbonate.
In the O. F. dissoves to a clear glass, feebly yellowish while hot, colorless on cooling, and cloudy when much is added. In the R. F. the glass is unchanged. On coal the oxide is reduced, volatilizes, and coats the coal again with oxide. The flame is violet even in presence of soda.	As with borax, but the glass, when treated with tin on coal, becomes gray and cloudy on cooling.
As with sodium carbonate.	As with sodium carbonate.

TABLE II. — Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
13. IRON SESQUIOXIDE. Fe_2O_3.	O. F. : Not changed. R. F. : Becomes black and magnetic, Fe_3O_4.	O. F. : Insoluble. R. F. : On Ch. it is reduced; the mass, when placed in a mortar, pulverized, and repeatedly washed with water to remove the adherent Ch. particles, yields a gray metallic powder which is attracted by the magnet, Fe_3O_4.
14. LANTHANUM SESQUIOXIDE. La_2O_3.	Unchanged.	Insoluble. The soda is absorbed by the coal, leaving the gray oxide behind.
15. LEAD OXIDE. PbO.	Minium, when heated on platinum foil, blackens; on increasing the temperature it changes into yellow oxide, which finally fuses to a yellow glass. On Ch. in O. F. and R. F. almost instantaneously reduced to metal which, with continued blowing, vaporizes, and covers the Ch. with yellow oxide, surrounded by a faint white ring of carbonate. The Ct., when touched with the R. F., disappears, imparting to the flame an azure-blue tinge.	O. F. : On platinum wire readily dissolved to a limpid glass, which, on cooling, becomes yellowish and opaque. R. F. : On Ch. reduced to metal which, with continued blowing, covers the Ch. with oxide.

TABLE II. — Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F. : A small amount of oxide causes the glass to look yellow while hot, colorless when cold. When more of the oxide is present the glass, while hot, appears red, and yellow when cold. A still larger quantity makes the glass dark-red while hot, and dark-yellow when cold. R. F. : The glass becomes bottle-green. Treated on Ch. with tin it becomes, at first, bottle-green, but afterwards pure vitriol-green.	O. F. : When at a certain point of saturation the glass, while hot, appears yellowish-red, and becomes on cooling at first yellow, then greenish, and finally colorless. On a very large addition of oxide it appears, while hot, deep-red, becoming, on cooling, brownish-red, then of a dirty-green color, and finally less brownish-red. R. F. : A glass containing but little of the oxide suffers no visible change. When more of the oxide is present it is red while hot, and on cooling becomes at first yellow, then greenish, and finally reddish. Treated with tin on Ch. the glass on cooling becomes at first green, and finally colorless.
In the O. F. dissolves to a clear, colorless glass, that becomes enamel-white by flaming when saturated to a certain extent, and when strongly saturated becomes enamel-like of itself on cooling. In R. F. the same as in O. F.	As with Borax.
O. F. : Easily soluble to a limpid yellow glass which, on cooling, becomes colorless. If much oxide be present it may be made cloudy by flaming. A still larger addition of oxide causes the bead to become enamel-yellow on cooling. R. F. : The glass diffuses itself over the Ch. and becomes cloudy. With continued blowing the oxide is reduced to metal, with effervescence, and the glass becomes clear again.	O. F. : As with borax. But to obtain a glass which appears yellow while hot, a large addition of the oxide is required. R. F. : On Ch. the glass becomes grayish and cloudy. This phenomenon is better observed when tin is added; but the glass can never be made quite opaque. If much of the oxide be present, the Ch. becomes coated.

TABLE II. — Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
16. MANGANESE DIOXIDE. MnO_2.	O. F. : Infusible. When the temperature is sufficiently high, both the sesquioxide and the peroxide are converted into a reddish-brown powder, Mn_3O_4. R. F. : The same effect.	O. F. : On platinum wire or foil a very small quantity dissolves to a transparent green mass, which on cooling becomes opaque and bluish-green. R. F. : On charcoal it cannot be reduced to metal; the soda passes into the charcoal and leaves the oxide behind.
17. MERCURY OXIDE. HgO.	Instantly reduced and volatilized.	Heated in a matrass to redness, it is reduced and vaporized. The vapors condense in the neck of the matrass and form a metallic coating, which can be united to a globule by carefully tapping on the matrass.
18. MOLYBDENUM TRIOXIDE. MoO_3.	O. F. : Fuses, becomes brown, vaporizes, and deposits on the Ch. a yellow Ct., which nearest to the assay is crystalline. On cooling the Ct. becomes white, and the crystals colorless. Beyond this coat is a thinner non-volatile film of dioxide, which on cooling is dark copper-red, with metallic lustre. R. F. : The greater part of the assay is absorbed by the Ch., and may be reduced to metal at a sufficiently high temperature; the metal is in the shape of a gray powder.	O. F. : On platinum wire dissolves with effervescence to a limpid glass, which on cooling becomes milk-white. R. F. : Fuses with effervescence. The fused mass is absorbed by the Ch., and part of the acid is reduced to metal which may be obtained as a steel-gray powder.

TABLE II. — Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F. : Colors very intensively. The glass, while hot, is violet, on cooling it assumes a reddish tinge. When much manganese is added, the glass becomes quite black and opaque; but the color can be seen when the glass, while soft, is flattened with the forceps. R. F. : The glass becomes colorless. If the color is very dark, the phenomenon is best observed on Ch. with addition of tin.	O. F. : A considerable addition of manganese must be made to produce a colored glass; it then appears, while hot, brownish- violet, and reddish-violet when cold, but never opaque. If the glass contain so small a quantity of manganese that it appears colorless, an addition of nitre will produce the characteristic coloration. A glass containing oxide bubbles and yields gas at a high temperature. R. F. : Becomes very soon colorless, and remains then quiet.
O. F.: Dissolved in large quantities to a limpid glass, which, while hot, appears yellow, but colorless on cooling. A very large amount of oxide causes the glass to appear dark-yellow while hot and opaline when cold. R. F.: A highly saturated bead becomes brown, and opaque when still more oxide is present. In a good flame black flocks of MoO_2 separate, and are visible in the yellow glass if flattened.	O. F.: Easily soluble to a limpid glass. If but little of the acid be present it is yellowish-green while hot, but when cold almost colorless. On the charcoal the glass becomes very dark, and on cooling assumes a beautiful green color, from the dioxide produced by the reducing action of carbon monoxide. R. F.: The glass assumes a very dark, dirty-green color, which on cooling becomes beautiful bright-green. The same on charcoal; tin deepens the color a little.

TABLE II. — Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
19. NICKEL MONOXIDE. NiO.	O. F. : Not changed. R. F. : On Ch. reduced to metal; the spongy mass cannot be fused to a globule, but assumes metallic lustre by friction; it is attracted by the magnet.	O. F. : Insoluble. R. F. : Easily reduced to metal, in the shape of bright, white scales, which are attracted by the magnet, if the particles of coal be washed away.
20. NIOBIUM PENTOXIDE. Nb_2O_5.	In O. F. becomes yellowish, but white again on cooling. In R. F. the same.	In O. F., with equal volume of soda, fuses with effervescence; with more soda, sinks into the coal. In R. F. the same. It cannot be reduced to metal.

TABLE II.—Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F. : A small quantity colors the bead violet while hot; when cold, pale reddish-brown. More oxide makes the coloration deeper. R. F. : The glass becomes gray and cloudy, or even opaque. With continued blowing the minute particles of reduced metal collect together and the glass becomes colorless. This takes place more readily on Ch., especially when tin is added. The nickel then unites with the tin to a globule.	O. F. : Soluble to a reddish glass which, on cooling, becomes yellow. A larger addition causes the glass to appear brownish-red while hot, and reddish-yellow when cold. R. F. : On platinum wire not changed. On Ch. with tin it becomes, at first, gray and opaque; with continued blowing the nickel becomes reduced, and the glass clear again and colorless.
In O. F. dissolves easily to a clear, colorless glass, becoming opaque by flaming with a certain addition, and with more becomes opaque of itself when cool. In R. F. a glass which, after treatment in the O. F., becomes opaque of itself, on cooling remaining unaltered.	In O. F. dissolves largely to a clear glass, yellow while hot, but colorless on cooling. In R. F., with a large addition, the glass becomes brown. The addition of ferrous sulphate gives a blood-red bead.

TABLE II.—Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
21. OSMIUM DIOXIDE. OsO_2.	O. F.: Converted into osmic acid, which, without depositing a coating, volatilizes with its peculiar pungent odor. R. F.: Easily reduced to a dark-brown and infusible metallic powder.	Easily reduced to an infusible metallic powder, which may be obtained pure by washing away the coal.
22. PALLADIUM MONOXIDE. PdO.	Reduced at a red heat; but the metallic particles are infusible.	Insoluble. The soda passes into the charcoal, and leaves the palladium behind as an infusible powder.
23. PLATINUM DIOXIDE. PtO_2.	Like palladium.	Like palladium.
24. RHODIUM OXIDE. R_2O_3.	Like palladium.	Like palladium.
25. RUTHENIUM OXIDE. Ru_2O_3.	Like palladium.	Like palladium.
26. SILVER OXIDE. Ag_2O.	Easily reduced to metallic silver, which unites to one or more globules.	Instantly reduced. The soda passes into the charcoal, and the metal unites to one or more globules.
27. TANTALUM PENTOXIDE. Ta_2O_5.	In O. F. becomes slightly yellow, but is white again when cold. In R. F. the same. On addition of Cobalt becomes light-gray after long ignition, and turns slightly red, like magnesia, on cooling.	In R. F., with more than an equal volume of soda, fuses on coal to a bead with effervescence, and soon spreads out; with more soda, sinks into the coal. In R. F. the same. It cannot be reduced to metal.

TABLE II.—Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F. and R. F.: Reduced, but not dissolved; the metallic particles cannot be fused to a globule.	As with borax.
Like palladium.	Like palladium.
Like palladium.	Like palladium.
Like palladium.	Like palladium.
O. F.: In part dissolved and in part reduced. On cooling, the glass becomes opalescent or milk-white, according to the amount of oxide present. R. F.: The glass at first becomes gray, but afterward limpid and colorless, the silver being reduced.	O. F.: Imparts to the bead a yellowish color. When much of the oxide is present, the glass, when cold, is opalescent, and appears yellowish by daylight, reddish by candle-light. R. F.: As with borax.
In O. F. dissolves easily to a clear glass, which, with a certain amount, appears yellowish while hot, colorless on cooling, and can be made opaque by flaming. With still more the glass becomes enamel-white of itself on cooling. In R. F. same as in O. F.	In O. F. dissolves largely to a clear glass, which, with a very large amount, is yellowish while hot, but colorless on cooling. In R. F. the above glass is unchanged.

TABLE II.—Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
28. TELLURIUM DIOXIDE. TeO_2.	O. F.: Fuses, and is reduced with effervescence. The reduced metal becomes instantly vaporized and covers the charcoal with tellurium dioxide; the coating usually has a red or dark-yellow edge. R. F.: As in O. F.; the outer flame appears of a bluish-green color.	Soluble, on platinum wire, to a limpid and colorless glass, which, on cooling, becomes white. On charcoal reduced and volatilized, depositing a coating of tellurium dioxide.
29. THALLIUM MONOXIDE. Tl_2O.	Melts and is reduced with effervescence to metallic globules, which volatilize on continued blowing, and yield a slight white coating.	On charcoal is reduced to metal, with evolution of vapor and formation of a white coating.
30. TIN DIOXIDE. SnO_2.	O. F.: The protoxide burns, like tinder, to dioxide. The dioxide becomes very luminous, and appears, while hot, yellowish, but assumes on cooling a dirty-white color. R. F.: With a powerful and continued flame it may be reduced to metal, a trifle of dioxide being formed near the metal.	O. F.: On platinum wire it forms with soda, with effervescence, an infusible compound. R. F.: On charcoal reduced to metallic tin.

TABLE II.—Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F.: Soluble to a limpid and colorless glass, which, on charcoal becomes gray from reduced metal. R. F.: On charcoal becomes at first gray; afterward colorless. The charcoal becomes coated with tellurium dioxide.	As with borax.
In O. F. dissolves readily to a colorless glass. When the cooled bead is heated below redness, the surface is colored brown; if the heat be raised to redness, the bead becomes again colorless after slight blowing. In the R. F. the bead acquires a grayish turbidity, which disappears on continued blowing.	In O. F. dissolves to a clear glass, which, when slightly blown upon, becomes turbid. In R. F. on charcoal the yellow glass becomes gray and clouded.
O. F.: A very small quantity dissolves slowly to a limpid and colorless glass, which remains so on cooling, and not becoming opaque by flaming. R. F.: From a highly-saturated glass a part of the oxide may be reduced on charcoal.	O. F.: As with borax. R. F.: The glass, containing oxide, suffers no change on coal or platinum wire.

TABLE II.—Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
31. TITANIUM DIOXIDE. TiO_2.	O. F.: Assumes, on heating, a yellow color, and becomes white again on cooling. Suffers no other change. R. F.: As in O. F. Heated with cobalt solution, assumes a yellowish-green color, similar to that produced with zinc oxide.	O. F.: On charcoal it dissolves, with effervescence, to a dark-yellow glass, which, on cooling, crystallizes, and thereby evolves so much heat that the globule glows again strongly. When cold it is grayish-white to white. R. F.: As in O. F.; cannot be reduced to metal.
32. TUNGSTEN TRIOXIDE. WO_3.	O. F.: Not changed; at a very high temperature converted into dioxide by the action of the carbon monoxide. R. F.: Blackens, being converted into dioxide, but does not fuse.	O. F.: On platinum wire it dissolves to a limpid and deep-yellow glass, which, on cooling, becomes crystalline and opaque, and of white or yellowish color. R. F.: With very little soda on charcoal it is reduced to metal; with more soda it forms a yellow compound of metallic lustre which passes into the charcoal.
33. URANIUM TRIOXIDE. U_2O_3.	O. F.: Infusible; but assumes a dirty yellowish-green color. R. F.: Blackens, and shows this color also by friction in the mortar. U_3O_5.	O. F.: Insoluble. With a certain amount of soda the mass becomes yellowish-brown, and with more passes into the charcoal. R. F.: As in O. F.; no reduction to metal takes place.

TABLE II.—Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F.: Easily soluble to a limpid glass, which, when containing a large quantity, appears yellow while hot, but becomes colorless on cooling. When containing a very large quantity it is enamel-white when cold. R. F.: When containing but little titanium dioxide, the glass becomes yellow; when more, dark-yellow to brown. A saturated glass becomes enamel-blue by flaming.	O. F.: Easily dissolved to a limpid glass, which, when containing a large quantity, appears yellow while hot, but becomes colorless on cooling. R. F.: Appears yellow while hot, but on cooling reddens, and finally assumes a violet color. If iron be present, the glass, on cooling, becomes brownish-red; with tin, or if the amount of titanium be very small, metallic zinc, on charcoal, the glass becomes violet, unless the amount of iron be very considerable.
O. F.: Like titanium dioxide. R. F.: A glass containing but little tungsten trioxide is not changed. When more, it becomes yellow, and, on cooling, yellowish-brown. On charcoal the same reaction is produced with a less saturated bead. Tin deepens the colors.	O. F.: Easily dissolved to a limpid and colorless bead, which, when highly saturated, appears yellow while hot. R. F.: With little blowing the glass appears, while hot, of a dirty green color, blue on cooling; with strong blowing it becomes, on cooling, bluish-green. On charcoal with tin, deep-green. If iron be present, the glass, on cooling, becomes brownish-red; with tin on charcoal the glass becomes blue, or, if the amount of iron be considerable, green.
O. F.: Behaves like iron sesquioxide. When highly saturated the glass may be made enamel-yellow by flaming. R. F.: Behaves like iron sesquioxide. The green bead, when at a certain point of saturation, may be made black by flaming. On charcoal with tin it becomes dark-green.	O. F.: Dissolves to a limpid yellow glass, which, on cooling, becomes yellowish-green. R. F.: The glass assumes a dirty-green color, which, on cooling, changes to a fine green. With tin on charcoal the color deepens.

TABLE II.—Continued.

Metallic Oxides in Alphabetical Order.	*On Charcoal alone.*	*With Sodium Carbonate on Charcoal.*
34. VANADIUM PENTOXIDE. V_2O_5.	Fusible. Where it is in contact with the charcoal it becomes reduced and passes into the charcoal. The rest assumes the lustre and color of graphite, and consists of trioxide V_2O_3.	Unites to a fusible mass which is absorbed by the charcoal.
35. ZINC OXIDE. ZnO.	O. F.: When heated becomes yellow, and, on cooling, white again. It fuses not, but becomes very luminous. R. F.: Is slowly reduced; the reduced metal becomes rapidly reoxidized and the oxide deposited on another place of the charcoal, being yellowish while hot, and white on cooling.	O. F.: Insoluble. R. F.: On charcoal it becomes reduced. The metal vaporizes and coats the charcoal with oxide. With a powerful flame the characteristic zinc flame is sometimes produced.

TABLE II.—Continued.

With Borax on Platinum Wire.	*With Salt of Phosphorus on Platinum Wire.*
O. F.: Dissolved to a limpid glass, which, when the quantity of vanadium oxide is small, appears colorless, when larger, yellow, and which, on cooling, becomes greenish-yellow. R. F.: The glass, while hot, appears brownish, and assumes a fine chrome-green color on cooling.	O. F.: Soluble to a limpid glass, which, if sufficient vanadium oxide be present, appears dark-yellow while hot, and becomes light-yellow on cooling. R. F.: As with borax.
O. F.: Dissolves readily, and in large quantity, to a limpid glass, which appears yellowish while hot; on cooling, it is colorless. When much of the oxide is present, the glass may be made enamel-white by flaming; and on a still larger addition it becomes enamel-white on cooling. R. F.: The saturated glass becomes at first gray and cloudy, and finally transparent again. On charcoal the oxide becomes reduced, the metal vaporizes and coats the charcoal with oxide.	As with borax.

PART II.

DETERMINATIVE MINERALOGY.

CHAPTER VI.

ON THE DETERMINATION OF MINERALS BY MEANS OF THE BLOWPIPE, AIDED BY HUMID ANALYSIS.

By the methods given in the preceding chapters we can readily detect the constituents of most inorganic compounds, whether prepared artificially or occurring in nature; especially if heavy metals form the principal constituents. But these methods do not enable us to discriminate the different native silicates and other mineral bodies, which consist essentially of such substances as do not show any very characteristic reactions before the blowpipe. In some cases we may succeed in ascertaining the principal ingredients of the substance under examination, but fail in establishing the mineral species. To attain this end more securely, we must pursue a course composed of an examination of the physical properties of the body and of blowpipe operations, aided by humid analysis. The course adopted in this "Manual" is that given by Franz von Kobell, as laid down in his "Tafeln zur Bestimmung der Mineralien," 11th edition.

The minerals, according to Von Kobell's system, are arranged in two large groups, the first embracing those possessing metallic lustre, the second those devoid of metallic lustre. To avoid mistakes, originating in the

fact that some minerals occur sometimes with, and sometimes without, metallic lustre, these minerals will generally be found enumerated in both groups.

The same precaution has been taken in regard to those species in which the degree of fusibility, whether below or above 5, may appear doubtful.

In the examination of a mineral it is necessary to begin with the first group, and proceed to the following in the order given, for often a mineral belonging to one group has the characteristics of a following one; but the latter may not show the reactions of the former.

The same care is necessary in observing the distinctions between the various divisions, sections, and species.

These divisions are based upon the following properties, and are determined as follows:

1. **Lustre.** In the group of minerals with metallic lustre are placed only those which are perfectly opaque.

If a thin splinter is held between the eye and the light, or placed upon a piece of white porcelain, and shows no translucency, it is considered as having metallic lustre; otherwise as without it.

Moreover, the mineral should have the appearance of some metal as to lustre, and retain this to some extent at least after it is powdered.

The minerals without metallic lustre yield an earthy powder, as well as some with the metallic, which in other respects might be considered as metallic.

Fusibility. The degree of fusibility may be determined by the following scale:

1. Stibnite. Fusible in coarse fragments in the flame of a candle.

2. Natrolite. Fusible in fine splinters in the flame of a candle.

3. Almandite (Alumina-iron garnet). Easily fusible before the blowpipe, but infusible in the flame of a candle.

4. Actinolite. Fusible in coarse splinters before the blowpipe.

5. Orthoclase. Fusible in fine splinters before the blowpipe.

6. Bronzite. Fusible on the points and edges of very fine splinters before the blowpipe.

In order to test the fusibility of a mineral, a small splinter, having a sharp edge or point, should be broken off and held in the forceps at a short distance beyond the point of the inner blue flame, so that the sharp edge is strongly heated. If a gas flame be employed, the mineral must be held somewhat farther from the point of the blue flame than is necessary in the case of an oil-lamp, in order to prevent any reduction taking place, which would materially interfere with the results. If a powdered substance is to be tested, or one which decrepitates when heated, and which must therefore be previously pulverized, the following process may be resorted to: A small quantity of the powder is made into a paste with water and spread upon a piece of charcoal; it is then dried and strongly heated with an oxidizing flame; it will then (generally) cohere sufficiently to allow of its being taken up between the forceps and tested in the usual manner. Care must be taken that the substance, if a fusible one and one which acts upon platinum, does not fuse upon the platinum points of the forceps.

The fusibility, when the same as actinolite, is designated by 4; when between that of natrolite and almandite, by 2.5; and so on.

A list of oxidized minerals, arranged according to their fusibility and behavior with sodium carbonate be-

fore the blowpipe, may be found at the end of this chapter, page 291.

Hardness. The scale of hardness, as introduced by Mohs, consists of the following minerals:

1. **Talc**: Common laminated, light-green variety.
2. **Gypsum**: Crystalline variety.
3. **Calcite**: Transparent variety.
4. **Fluorite**: Crystalline variety.
5. **Apatite**: Transparent variety.
6. **Orthoclase**: White cleavable variety.
7. **Quartz**; Transparent.
8. **Topaz**: Transparent.
9. **Corundum**: Cleavable varieties.
10. **Diamond.**

The hardness of a mineral may be determined by attempting to scratch it with the minerals enumerated in the scale, or by abrasion with a file. If the file abrades the mineral under trial with the same ease as No, 4, and produces an equal depth of abrasion with the same force, its hardness is said to be 4. If with more facility than 4, but less than 5, the hardness may be 4.2 or 4.5. Several trials should be made to obtain accurate results; and, when practicable, both methods should be employed.

In case a set of minerals like the above is not at hand we may estimate the hardness as follows:

1. Yields easily to the finger-nail.

2. Yields with difficulty to the nail; does not scratch a copper coin.

3. Scratches a copper coin; is also scratched by it, being of about the same degree of hardness.

4. Not scratched by a copper coin; does not scratch glass.

5. Scratches glass, though with difficulty, leaving its powder upon it. Yields readily to the knife.

6. Scratches glass easily. Yields with difficulty to the knife.

7. Does not yield to the knife. Yields to the edge of a file, though with difficulty.

8, 9, 10. Harder than flint.

Color. The color of metallic minerals changes on exposure to the air and light, and a fresh fracture should therefore be examined. With non-metallic minerals the color varies greatly.

Streak. This is determined by rubbing the mineral upon a piece of unglazed porcelain and observing the color of the mark produced. If the mineral is very hard, it may be tested by scratching with a knife or file. The streak of metallic minerals is generally darker than the color of the specimen, and the streak of the non-metallic is lighter.

Specific gravity. The ordinary chemical balance can be used for its determination, but the Jolly balance, described on page 30, will be found much more convenient for this purpose.

Crystallization and **cleavage,** if distinct, will often aid largely in determining the species of the mineral.

The systems of crystallization are as follows:

I. Isometric. The three axes equal in length and rectangular in intersections.

II. Dimetric or **Tetragonal.** The two lateral axes equal and unequal to the vertical; rectangular in intersections.

III. Trimetric or **Orthorhombic.** The three axes unequal and rectangular in intersections.

IV. Monoclinic. The three axes unequal, and only one oblique inclination made by the intersection.

V. Triclinic. The three axes unequal, and all obliquely inclined to one another.

VI. Hexagonal. The vertical axis at right angles to the three lateral, which intersect at angles of 60°.

Water and formation of **Hepar** may be determined by methods already given (pars. 9 and 11).

For most hydrates the temperature of a good gas flame is sufficiently high, but for some silicates, especially the magnesium, the strongest blast flame is necessary, with long-continued heating.

Decomposition by acids. For this test the mineral should be ground as fine as possible in an agate mortar, and placed in some vessel in which the action of the acid and color of the solution can be distinctly seen, and boiled for a quarter of an hour if necessary. If there is no apparent change in the powder, the liquid should be decanted or filtered, and then tested with ammonium carbonate in excess and a few drops of sodium phosphate. If no precipitate or cloudiness is formed, the mineral has not been decomposed.

Formation of a jelly. If silicates finely powdered are heated with phosphoric acid until the acid begins to fume, then cooled, water poured over the substance and evaporated by boiling, the silica separates in form of a jelly. Many silicates gelatinize after ignition, as, for example, garnet, vesuvian, etc. Some splinters or small fragments of the assay are fused or ignited, finely powdered, and boiled in a test-tube with dilute acid. On evaporation, lumps of jelly may be seen, or, if left standing for some time (twelve hours), a stiff jelly may be formed. If water is added, stirred with a glass rod, and then filtered, the solution may be tested for bases with ammonium hydrate, ammonium oxalate, etc., for alumina, lime, etc.

Pyro-electricity. Electricity is developed in some

minerals by heat. They may be tested with a deer's hair or with fibres of wool or cotton.

When the mineral is transparent, a Nicol prism and the Von Kobell stauroscope will be needed for determining its optical properties.

It is scarcely necessary to add that only pure and homogeneous material will give definite and satisfactory reactions. If the material is found to be impure, regard must be had to this fact, and conclusions made accordingly. Many specimens of wollastonite effervesce with acids—a property which does not belong to the mineral, but comes from the calcite mixed with it.

Well-known species, with marked characteristics, should be studied until some practice is acquired, and then others requiring more careful observation and study may be examined.

SYNOPSIS OF TABLES.

GROUP I. MINERALS WITH METALLIC LUSTRE.

(Of those minerals whose lustre may be uncertain, only such are placed in this group as are perfectly opaque.)

CLASS I. Native malleable metals and mercury, page 226

CLASS II. Fusibility 1–5, or readily volatile.

Division 1. Before the blowpipe on charcoal give the strong garlic odor of *arsenic*, . . . p. 227

Division 2. Before the blowpipe on charcoal, or in the open tube, give the horse-radish odor of *selenium*, p. 229

Division 3. Before the blowpipe on charcoal give a white coating, and color the reducing flame green; in presence of selenium, greenish-blue. If *gently* heated in a small test-tube with an excess of concentrated sulphuric

acid, it colors the acid hyacinth-red; but if water is added the color disappears, and grayish-black *tellurium* is precipitated, ... p. 230

Division 4. Before the blowpipe on charcoal give *antimony* fumes, ... p. 231

Division 5. Before the blowpipe on charcoal give with soda a *sulphur* reaction, or, heated in an open glass tube, give off sulphur dioxide, but do not give reactions of the preceding divisions, ... p. 233

Division 6. Do not belong to the preceding divisions, ... p. 235

CLASS III. Infusible, or fusibility above 5, and not volatile.

Division 1. Before the blowpipe give to the borax bead, in very small quantities in the oxidizing flame, an amethyst color (*manganese*), ... p. 236

Division 2. Magnetic, or before the blowpipe on charcoal become so, if strongly heated in the reducing flame, ... p. 237

Division 3. Not belonging to the preceding divisions, ... p. 238

GROUP II. MINERALS WITHOUT METALLIC LUSTRE.

CLASS I. Easily volatile, or combustible, . p. 239

CLASS II. Fusibility 1–5; not, or only partially, volatile, ... p. 240

PART I. Before the blowpipe with soda on charcoal give a metallic globule, or, fused alone in reducing flame, a magnetic metallic mass.

Division 1. Before the blowpipe give with soda a globule of *silver*, ... p. 240

Division 2. Before the blowpipe give with soda a globule of *lead*, ... p. 240

Division 3. Before the blowpipe, moistened with hydrochloric acid, color the flame blue, and give with nitric acid a solution which, on addition of an excess of ammonium hydrate, assumes an azure-blue color (*copper*).

Section 1. Before the blowpipe on charcoal give a strong *arsenic* odor, ... p. 243

Section 2. Before the blowpipe on charcoal give *no arsenic* odor, ... p. 244

Division 4. Before the blowpipe impart to the borax bead a sapphire-blue color (*cobalt*), . . . p. 245

Division 5. Before the blowpipe fused in forceps, or on charcoal in reducing flame, give a black or gray metallic magnetic mass.

Section 1. Give during fusion on charcoal a strong *arsenic* odor, ... p. 245

Section 2. Soluble in hydrochloric acid, without leaving a perceptible residue and without gelatinizing, . . p. 246

Section 3. With hydrochloric acid gelatinize or decompose, with separation of silica, ... p. 248

Section 4. But little affected by hydrochloric acid, p. 250

Division 6. Not belonging to either of the preceding divisions, ... p. 251

PART II. Fused with soda on charcoal give no metallic globule, or, fused alone in reducing flame, no magnetic metallic mass.

Division 1. After fusion and continued heating on charcoal in the forceps or on platinum foil, have an alkaline reaction, and change to reddish-brown the color of moistened turmeric paper. (Fragments, and not powder, should be used.) . . . . .

Section 1. Easily and completely soluble in water, p. 252
Section 2. Insoluble, or difficultly soluble in water, p. 254
Division 2. Soluble in hydrochloric acid without leaving a perceptible residue; some also soluble in water; not gelatinized by evaporation, ... p. 255
Division 3. Soluble in hydrochloric acid, forming a stiff jelly, especially after partial evaporation.
Section 1. Before the blowpipe in a matrass give water, p. 257
Section 2. Before the blowpipe in a matrass give no water, or only traces, ... p. 258
Division 4. Soluble in hydrochloric acid, with separation of silica, without forming a perfect jelly.
Section 1. Before the blowpipe in a matrass give water, p. 260
Section 2. Before the blowpipe in a matrass give no water, or only traces, ... p. 263
Division 5. Little affected by hydrochloric acid. Before the blowpipe give an amethyst color to the borax bead (*manganese*), ... p. 264
Division 6. Not belonging to the preceding divisions, ... p. 265

CLASS III. Infusible, or fusibility above 5.

Division 1. After ignition, moistened with cobalt solution and again ignited, assume a bright-blue color (*alumina*).
Section 1. Before the blowpipe in a matrass give much water, ... p. 271
Section 2. Before the blowpipe in a matrass give no water, or but a trace, ... p. 274
Division 2. Moistened with cobalt solution and ignited assume a green color (*zinc*), . . . p. 276

Division 3. After ignition have an alkaline reaction and change to reddish-brown, the color of moistened turmeric paper, ... p. 276

Division 4. Completely soluble, or nearly so, in hydrochloric or nitric acid, without gelatinizing by evaporation or leaving a considerable residue of silica, . p. 278

Division 5. With hydrochloric acid gelatinize or decompose, with separation of silica.

Section 1. Before the blowpipe in a matrass give water, p. 281

Section 2. Before the blowpipe in a matrass give no water, or but a trace, ... p. 283

Division 6. Not belonging to either of the preceding divisions.

Section 1. Hardness below 7, ... p. 284

Section 2. Hardness 7, or above 7, . . . p. 288

GROUP I. MINERALS WITH METALLIC LUSTRE.

(Of those minerals whose metallic lustre is doubtful, only such as are perfectly opaque are included in this group.)

CLASS I. Native malleable metals and mercury.

Maldonite, Au_2Bi. Color, silver-white streaked with black. Easily fusible on charcoal, giving a bismuth coating and a gold bead.

Silver, see par. 286, Chapter VII. **Gold** and *Electrum* (alloy of silver and gold), see par. 235.

Copper, see par. 218.

Lead, characterized by coating on charcoal (see par. 27) and softness; H. = 1.5.

Platinum, see par. 237. *Iridosmine* (IrOs), see par. 238.

Palladium, distinguished from the preceding by being soluble in nitric acid. Color steel-gray. Infusible.

Native Iron, see par. 239.

Mercury, see par. 276. *Amalgam* Ag, Hg, and Ag_2Hg_3.

Argentite and *Hessite* are malleable, for which see par. 287 and p. 230.

CLASS II. Fusibility 1–5, or readily volatile.

Division 1. Give a strong arsenic odor on charcoal.

Arsenic, see par. 203.

Dufrenoysite, see par. 170; *Sartorite,* $PbAs_2S_4$. Before the blowpipe nearly the same as dufrenoysite, but decrepitates strongly; H. = 3. *Jordanite,* $Pb_3As_4S_9$. Color, lead-gray; streak black. *Tennantite,* $Cu_8As_2S_7$. Color, iron-black; streak gray. *Epigenite* $(Cu,Fe)_9As_2S_{12}$, similar in its properties, but is trimetric in crystallization.

Polybasite, see par. 293. **Domeykite,** see par. 222.

Binnite, $Cu_6As_4S_9$. In the closed tube gives a sublimate of arsenic sulphide; in the open tube, a crystalline sublimate of arsenic trioxide, with sulphur dioxide. Before the blowpipe on coal gives a faint white coating and odor of arsenic; with soda fuses to a globule, giving metallic copper. Lustre metallic; color black on fresh fracture; streak cherry-red; brittle. H. = 4.5; G. = 4.4.

Enargite, Cu_3AsS_4. In the closed tube decrepitates and gives a sublimate of sulphur; in the open tube gives off sulphur dioxide and arsenic trioxide, the latter condensing to a sublimate containing often antimony trioxide. The roasted mineral gives a globule of copper with fluxes. Lustre metallic; color and streak grayish-black; brittle; fracture uneven. H. = 3; G. = 4.4.

Rionite $(Cu,Fe)_6(As,Bi)_2S_8$. With sulphur and potassium iodide gives the red bismuth sublimate.

Algodonite, Cu_6As. H. = 4; G. = 7.6. See par. 222.

Whitneyite, Cu_9As. Less fusible than algodonite; otherwise as in domeykite. Massive; crystalline; very fine granular. Lustre dull, but strong metallic where scratched; soon tarnishing. Color bronze to reddish-white, becoming brown and black on exposure. Malleable. H. = 3.5; G. = 8.3.

Smaltite, see par. 214; **Cobaltite**, see par. 215.

Skutterudite, Co,As_3; *Glaucodot* (Co,Fe), AsS; *Alloclasite* $(Co,Fe,Zn)_4(As,Bi)_7S_6$. Before the blowpipe all give a sapphire-blue color to the borax bead. Decomposed with nitric acid, with separation of arsenic trioxide, forming a red solution. In a concentrated solution of alloclasite, water gives a cloudiness, but not in the others. Smaltite, skutterudite, and glaucodot, heated in a matrass, give a sublimate of metallic arsenic. Cobaltite gives none. The strong acid and dilute solutions of cobaltite and glaucodot give a precipitate with barium chloride; the solutions of smaltite and skutterudite, none or a very small one. Smaltite has octahedral cleavage; skutterudite, cubical.

Some varieties contain nickel and resemble chloanthite, in which case the nitric acid solution is green. The nickel varieties are distinguished by decomposing the powdered mineral with a small amount of concentrated nitric acid, carefully neutralizing with ammonia without filtering, and afterward filtering without diluting. The filtrate will have a fine blue color.

Glaucopyrite, Fe, Co, Cu, Sb, As, S. Reactions similar to glaucodot. H. = 4.5; G. = 7.18.

Compare the following minerals, also native bismuth, which often contain cobalt as an impurity:

Niccolite, see par. 280; *Gersdorffite*, see par. 281; *Chloanthite* or *Chathamite* (var. of *Smaltite*), $(Co,Fe,Ni)As_2$,

distinguished from gersdorffite by not giving the reactions for sulphur. The proportions of Fe, Ni, and Co vary greatly.

Rammelsbergite, $NiAs_2$ (similar to chloanthite). In closed tube gives a sublimate of metallic arsenic. See also *Corynite*, Ni(As,Sb)S, which before the blowpipe, on coal, gives the smell of arsenic and fumes of antimony. Color silver-white to steel-gray. *Wolfachite*, Ni(As,Sb)S. Similar in composition, but trimetric in form. See *Ullmannite*, page 282; *Arsenopyrite*, see par. 243.

Lölingite, $FeAs_2$. Fuses only on the surface, and with difficulty after the arsenic is driven off. G. = **6.8–8.7.**

Compare also bismuth and antimony, which often contain arsenic, but are easily recognized by the white or yellow coating on coal. *Proustite* and *Pyragyrite* often have metallic lustre, but are recognized by their red streak. See pars. 290, 291. *Geocronite* also contains arsenic, see par. 256.

Division 2. Before the blowpipe on charcoal, or in an open tube, give the horse-radish odor of selenium.

Tiemannite, HgSe, *Lehrbachite* (Hg,Pb)Se. Mercury and lead selenide yield metallic mercury on being heated with soda in a closed glass tube (par. 105); the latter yields a globule of metallic lead on being heated on charcoal with soda.

Gaudalcazarite (Hg,Zn)(S,Se). General properties like the preceding, but gives the sulphur reaction.

Clausthalite, PbSe. Color lead-gray; volatilizes without previous fusion, depositing first a slight gray, then a white, and finally a yellowish-green coating; with soda yields with difficulty globules of lead.

Naumannite $(Ag,Pb)_5Se_3$. Color iron-black; melts readily, and yields with borax a globule of pure silver.

Berzelianite, Cu_2Se, and *Eucairite* $(Cu,Ag)_2Se$. Color of the former silver-white; of the latter lead-gray. Distinguished from the foregoing minerals of this division by giving copper reactions.

Crookesite $(Cu_2Tl,Ag)Se$, is similar, containing 17.25 per cent. of thallium, and coloring the flame bright-green. *Zorgite* $(Pb,Cu_2)Se$, colors the flame blue.

Division 3. Before the blowpipe on charcoal give a white coating and color the reducing flame green; in presence of selenium, greenish-blue.

The assay-piece used for this experiment ought not to be very small. It must be borne in mind that the minerals of this division frequently evolve an odor of selenium, owing to a small percentage of selenium which they contain as adventitious constituent.

The minerals of this division may be subdivided according to their color.

a. Ores of tellurium, of *tin-white*, *silver-white*, or *reddish-white* color.

Native Tellurium fuses readily and is volatile without leaving a residue.

Melonite, Ni_2Te_3. Hexagonal; reddish-white, dark-gray streak.

Hessite, Ag_2Te (sectile), and *Altaite*, PbTe, and some varieties of sylvanite (par. 236), yield with soda on charcoal a globule of metallic silver, with sometimes considerable gold. In *Petzite* $(Ag,Au)_2Te$ (brittle), nearly all the silver is replaced by gold. *Müllerite*, Au, Ag, Pb, Te, and Sb.

b. Ores of tellurium, of *lead-gray* or *steel-gray* color.

Tetradymite, see par. 209. *Sylvanite,* see par. 236. *Joseite* $Bi_{12}Te_4SeS_3$.

Nagyagite $(Pb,Au)(Te,S)_2$. Color, blackish lead-gray. Distinguished from the preceding by its solution in nitric acid giving a copious precipitate with sulphuric acid. Compare aikenite.

Division 4. Before the blowpipe on charcoal give antimony fumes (see par. 16) with a pure white coating.

The fumes possess sometimes the odor of sulphur dioxide or arsenic.

Antimony, distinguished by its tin-white color. Before the blowpipe it takes fire and burns without blowing, and becomes covered with white needles of antimony oxide. **Stibnite,** see par. 200; *Zinkenite,* see par. 256; **Jamesonite,** see par. 256; **Bournonite,** see par. 256.

The powdered stibnite, on being treated with caustic potash, assumes a yellow color, and is for the most part dissolved, while the latter three minerals, which are steel- or lead-gray, do not change color. Bournonite, on being treated with nitric acid, imparts to the solution a sky-blue color. This solution, with sulphuric acid, gives a white precipitate of lead sulphate, and with an excess of ammonia becomes violet-blue. *Stylotypite* $(Cu_2Ag_2Fe)_3Sb_2S_6$, is similar to bournonite, but no precipitate is formed with sulphuric acid from its solution in aqua regia. Zinkenite and jamesonite are converted into white powders by treatment with nitric acid, without imparting a color to the acid; they are distinguished by their hardness, that of zinkenite being 3.5, that of jamesonite, 2.5. The former has no cleavage, while in the latter it is very marked in one direction.

Closely resembling the above in their chemical behavior are the following rare minerals: *Boulangerite*, see par. 256; **Geocronite**, see par. 256; *Plagionite*, see par. 256; *Meneghenite*, see par. 256.

Kobellite, Pb_3BiSbS_6. Color lead-gray; soft and fibrous. With sulphur and potassium iodide gives the bismuth reaction. The nitric acid solution gives a white precipitate with sulphuric acid.

Freibergite $(CuAg)_8Sb_2S_7$. Color steel-gray. Gives the silver, sulphur, and copper reactions. H. = **3.5**; G. = **4.8.** Isometric.

Dyscrasite, see par. 289; **Stephanite**, see par. 292; some varieties of **Tetrahedrite**, see par. 225; *Miargyrite*, $AgSbS_2$. All give the sulphur reaction except dyscrasite. Tetrahedrite gives a copper reaction on being treated as described in par. 90. Miargyrite, streak dark cherry-red; stephanite, streak black; miargyrite and stephanite, H. = **2.5**; tetrahedrite, H. = **3.5.** All the minerals of this subdivision give a globule of silver on being treated as described in par. 117, or 118.

Brongniardite, $Ag_2PbSb_2S_5$. Isometric; fuses easily. Dissolved in nitric acid, lead sulphate is precipitated by sulphuric acid.

Freieslebenite, $Pb_2Ag_3Sb_3S_8$, behaves in the same way, but is monoclinic. Compare also *Pyrargyrite*.

Spaniolite $(Cu_2Hg)_4Sb_2S_7$, mixed with soda and iron filings, covered with copper foil, and heated in a glass tube, yields mercury. The nitric acid solution, with an excess of ammonia, becomes blue.

Chalcostibite [antimonial copper], $CuSbS_2$, does not give a globule of silver, but yields a globule of metallic copper on being treated with soda on charcoal. Color lead-gray to iron-gray.

Ullmannite, see par. 282; **Berthierite**, see par. 201; *Breithauptite*, Ni,Sb. All yield a magnetic globule with continued heat. Breithauptite is distinguished from the other two by not giving a sulphur reaction. Color bright copper-red.

Division 5. Before the blowpipe on charcoal give with soda a sulphur reaction, but do not give the reactions of the preceding divisions.

Argentite, see par. 287; *Jalpaite*, see par. 287; *Acanthite*, see par. 287.

Galenite, see par. 255.

Cinnabar, see par. 277. *Metacinnabarite* is amorphous HgS; streak black; H. = 3; G. = 7.72.

Alabandite, MnS. Isometric. H. = 3.5. Color iron-black; powder leek-green; lustre submetallic.

Hauerite, MnS_2. H. = 4. Color brownish-black; powder brownish-red; lustre metallic adamantine. Yields sulphur on being heated in a matrass. These manganese minerals, boiled with a mixture of phosphoric and nitric acids, give a fine violet solution. In the borax bead give also a violet color.

Chalcocite, see par. 219; *Stromeyerite*, see par. 288; **Stannite**, see par. 298; **Chalcopyrite**, see par. 220; **Bornite**, see par. 221; *Cubanite*, $Cu_4Fe_2S_4$; *Wittichenite*, Cu_3BiS_3; *Emplectite*, $CuBiS_2$, color tin-white; *Aikinite*, $CuPbBiS_3$; *Grünauite*, Ni,Bi,Fe,Cu,S; *Cuproplumbite*, $Cu_2S,2PbS$; *Pentlandite* (Ni,Fe)S. All these minerals are partially soluble in nitric acid, the solution possessing a sky-blue or green color; on addition of water to the concentrated solution, a white precipitate is produced if the mineral under examination were wittichenite, grünauite, or aikinite. [To distinguish these three, add to

the acid solution sulphuric acid: a precipitate indicates aikinite; wittichenite gives the copper reaction on being treated as described in par. 90; grünauite not.] Chalcopyrite and cubanite are distinguished from the others by their brass-yellow color; bornite is also characterized by its color. To distinguish the remaining four minerals, make a solution in nitric acid; add sulphuric acid: a precipitate indicates cuproplumbite; if no precipitate is produced, add hydrochloric acid: a precipitate indicates stromeyerite; to distinguish between chalcocite and stannite, see pars. 219 and 298. *Castillite* resembles bornite.

Huascolite, a zinciferous variety of galenite.

Millerite, see par. 279; **Linnæite**, see par. 213; **Pyrite**, see par. 240; **Marcasite**, see par. 241; **Pyrrhotite**, see par. 242; *Sternbergite*, $AgFe_2S_3$. The members of this subdivision fuse to globules which are attracted by the magnet. They are readily distinguished by the characteristics given in Chapter VII. Sternbergite, by the treatment described in par. 117, yields a globule of silver. Marcasite, trimetric, and pyrite, isometric, can only be distinguished by their crystalline form.

Carrollite, Co_2CuS_4. Tin-white color. Reactions similar to linnæite, but also, when moistened with hydrochloric acid, gives a blue color to the flame.

Beyrichite, Ni_5S_7. Color lead-gray. Reactions like millerite, but gives sulphur in the closed tube.

Bismuthinite, see par. 208; **Chiviatite** $(Pb,Cu_2)_2Bi_6S_{11}$. Decomposed with nitric acid, with separation of lead sulphate.

Bismite, Bi_2O_3. Pulverulent or earthy. Color greenish-yellow to white.

Division 6. Do not belong to the preceding divisions.

Amalgam, see par. 276; *Arquerite*, see par. 276.

Bismuth, see par. 207.

Rabdionite, $(Cu,Mn,Co)(MnFe)O_4$. Stalactitic; color black; streak metallic gray. Colors the borax bead blue; heated with phosphoric acid, colors the solution violet.

Hematite, see par. 244.

Cuprite, see par. 227. Often with weak metallic lustre.

Magnetite, see par. 246.

Hortonolite $(Fe,Mg)_2SiO_4$, yellowish-black, and **Fayalite**, Fe_2SiO_4, black, and both magnetic before ignition, and gelatinize in hydrochloric acid.

Wolframite $(Mn,Fe)WO_4$. H. = 5–5.5; G. = 7.1–7.5. Monoclinic. Lustre submetallic; streak dark reddish-brown to black; opaque; sometimes magnetic; color dark-grayish or brownish-black; fusibility 3. The pulverized mineral, on being boiled with aqua regia, is decomposed and assumes gradually a yellowish color. Boiled for some time with phosphoric acid, gives a fine blue syrup, especially after cooling (*tungsten*). If diluted with water it becomes reddish-yellow, and finally colorless. On the addition of iron filings and sulphuric acid, and shaking, it gradually becomes sapphire-blue. This solution, diluted with water, loses its color again after a little time. If the blue syrup is treated with phosphoric and nitric acids it becomes violet (*manganese*).

The variety *dianite*, when treated as above, gives, when boiled with tin foil and concentrated hydrochloric acid, and diluting with its volume of water, a sapphire-blue fluid; while with the tantalite and ordinary columbite the metallic acids remain undissolved and the filtrate colorless.

The color of this mineral is iron-black; the powder of yttrotantalite, grayish; of dianite, grayish-black, also reddish-brown; of columbite, brownish-black; of tantalite, brown.

Samarskite, Cb_2O_5,Ta_2O_5,WO_3,SnO_2,ThO_2,ZrO_2,UO_2, MnO, FeO, CeO, YO, CaO, H_2O. Color velvet-black; lustre of surface of fracture shining and submetallic; streak dark reddish-brown; fusibility 4.5. By fusing the pulverized mineral with potassium hydrate in a silver crucible, boiling the fused mass in water, it gives a green solution, which is filtered; hydrochloric acid gives a white precipitate. If this is boiled with concentrated hydrochloric acid and tin for a few minutes, an equal volume of water added, it gives a bright-blue solution.

Rhodonite, dark varieties, $MnSiO_3$, slightly acted upon by acids. In a fine powder turns white in hydrochloric acid, with slight separation of silica; in oxidizing flame, colors the borax glass amethyst.

Some varieties of *Psilomelane*, see par. 272.

Fayalite, Ilvaite, and **Allanite,** some varieties, see Div. 5, p. 249.

Plattnerite, PbO_2. Color iron-black; lustre metallic-adamantine; streak brown; opaque; easily reduced to metallic lead with soda. G. = 9.3.

CLASS III. Infusible, or fusibility above 5, and non-volatile.

Division 1. Before the blowpipe give to the borax bead, in very small quantities in the oxidizing flame, an amethyst color (*manganese*).

The members of this division are distinguished from each other principally by their physical properties.

The manganese oxides are more or less easily soluble

in hydrochloric acid, with evolution of chlorine. If powdered and boiled with phosphoric acid to a syrupy consistency, the solution becomes a fine violet color, which, diluted with water and shaken with some crystals of ferrous sulphate, becomes colorless.

Compare franklinite, in the next division, which is also magnetic.

Lithiophorite, $MnO_2, Al_2O_3, LiO, H_2O$, colors the flame carmine-red.

Braunite, see par. 270; *Hausmannite*, see par. 269; *Psilomelane*, see par. 273; **Pyrolusite,** see par. 268; **Franklinite,** some varieties, see par. 247; **Manganite,** H_2MnO_4. Color steel-gray to iron-black; streak dark reddish-brown. H. = 4. Yields much water in a matrass. Otherwise like braunite.

Crednerite, $Cu_3Mn_2O_9$. H. = 4.5. Lustre metallic; color iron-black to steel-gray; streak brownish-black. Moistened with hydrochloric acid, gives a fine blue color to the flame. Dissolved in hydrochloric acid with an excess of ammonia, a precipitate is formed and a blue solution, which is not the case with the foregoing.

Compare *Alabandite* and *Hauerite*.

Division 2. Magnetic, or, heated on charcoal in the reducing flame, become magnetic.

Lölingite and *Arsenopyrite*, some varieties are infusible, but may be distinguished by the arsenic odor given off on charcoal before the blowpipe.

Hematite, see par. 244; **Turgite,** see 250.

Franklinite, see par. 247. **Magnetite,** see par. 246.

Jacobsite $(Mn,Mg)(Fe,Mn)O_4$; *Magnesioferrite*, $Mg \cdot FeO_4$. Color and streak of both minerals black; more or less magnetic without heating; dissolve with difficulty in hydrochloric acid. After oxidation of the solution

with potassium chlorate, and precipitation with an excess of ammonia, sodium phosphate precipitates the magnesia. Jacobsite gives the manganese reactions.

Menaccanite, see par. 245.

Compare *Rutile*, *Arkansite*, and *Anatase*, which are often magnetic from the presence of titanic iron, or become so after continued ignition. They are scarcely attacked by hydrochloric acid.

Some varieties of **Limonite,** see par. 248, *Siderite*, and *Sphalerite*, see par. 300, have metallic lustre. See *Graphite*.

Division 3. Not belonging to the preceding divisions.

Chromite, see par. 212. *Cassiterite* often has a similar metallic lustre. Easily reduced on charcoal with potassium cyanide.

Molybdenite, MoS_2; **Graphite,** C., see par. 305. Both very soft; hardness 1.5. Molybdenite, when heated in the forceps, colors the flame greenish, and gives a sulphur reaction when treated as described in par. 121. Color bluish-gray; sectile and nearly malleable. Decomposed by nitric acid, leaving a white or grayish residue of molybdenum trioxide.

Perofskite, $CaTiO_3$. Isometric. Gives the reaction for titanic acid as described in par. 125. Distinguished by crystalline form.

Compare *Rutile* and *Brookite*, Div. 6, p. 287.

Iridosmine, see par. 238.

Tantalite, $Fe(Mn)Ta_2O_6$, and *Columbite*, $FeCb_2(Ta_2)O_6$; *Yttrotantalite* $(Fe,Ca,Y)_2(TaCb)_2O_7$. The color of these minerals is iron-black; yttrotantalite loses its color before the blowpipe and becomes yellowish or white; that of the others remains unchanged. Acids affect them but little. If tantalite and columbite are powdered, fused with caustic potash in a silver crucible, dissolved in water, and fil-

tered, a precipitate is formed with hydrochloric acid, which, boiled with dilute sulphuric acid, becomes white; on the addition of zinc the precipitate from the columbite becomes intense blue in the hot solution, and retains this color on the addition of water for a considerable time. The precipitate from tantalite is lighter colored, and loses its color quicker with water.

Compare *Polycrase*, Div. 4, p. 280, and *Æschynite*, Div. 6, p. 287.

Uraninite, U_3O_8. Color usually velvet-black; lustre greasy; partially soluble in nitric acid to a yellow liquid; the solution gives a sulphur-yellow precipitate with ammonia. Boiled with phosphoric acid gives an emerald-green solution. G. = 6.4–7.

GROUP II. MINERALS WITHOUT METALLIC LUSTRE.

CLASS I. Easily volatile, or combustible.

Native Sulphur, S. H. = 1.5–2.5; G. = 2. Completely volatile; burns with a blue flame and emission of sulphur dioxide. Color sulphur-yellow, honey-yellow, and gray or brown from impurities.

Realgar, see par. 205; **Orpiment**, see par. 204.

Arsenolite, see par. 206; **Kermesite**, see par. 202.

Valentinite, Sb_2O_3. Trimetric. Color white; streak white; lustre adamantine; does not change color with potassium hydrate; does not evolve sulphuretted hydrogen with hydrochloric acid, but dissolves easily.

Senarmontite, Sb_2O_3. Isometric. Lustre resinous, inclining to sub-adamantine; streak white.

Sal-ammoniac, NH_4Cl; *Mascagnite* $(NH_4)_2SO_4$ + aq. Color white. Both evolve ammonia with potassium hydrate; the former is volatile without previous fusion; the latter intumesces. It also gives a precipitate with barium chloride.

Cinnabar, see par. 277; *Calomel*, see par. 278.

Cotunnite, $PbCl_2$. H. = 2; G. = 5.2. Color and streak yellowish-white. Fuses easily on coal, volatilizes, and gives a white coating, the inner edge of which is tinged yellow; with soda on charcoal gives globules of metallic lead.

CLASS II. Fusibility 1–5; not, or only partially, volatile.

PART I. Give with soda on charcoal a metallic globule, or, fused alone in reducing flame, a magnetic metallic mass.

(All minerals without metallic lustre, which give the arsenic odor, belong to this group, excepting pharmacolite.)

Division 1. Give with soda a globule of silver.

(It is well to fuse the globule with borax, in order to have it quite pure and malleable.)

Proustite, see par. 291; **Pyrargyrite,** see par. 290; *Xanthoconite*, $Ag_9As_3S_{10}$, behaves like proustite, from which it is distinguished by its orange-yellow color and streak.

Compare *Myargyrite*, Div. 4, p. 232. which is often very similar to *Pyrargyrite*. The G. of the former is 5.2, and of the latter 5.7.

Cerargyrite, see par. 294; *Iodyrite*, see par. 297; *Embolite*, see par. 296. All malleable and sectile.

Division 2. Give with soda a globule of lead.

The minerals of this division are all soluble in nitric acid; the solution gives a copious precipitate with sulphuric acid. If dissolved by boiling with caustic potash, potassium chromate directly, or on addition of acetic acid, gives an orange precipitate.

Bindheimite, $Pb_3Sb_2O_8 + 4aq$, and *Nadorite*, PbSb ClO_2. Lustre resinous or dull; color and streak white, grayish-yellow. Before the blowpipe on coal give a coating of lead and antimony. The former in the matrass, water. The latter, fused in a salt of phosphorus bead with copper oxide, colors the flame blue (*copper chloride*).

Mimetite, $3Pb_3As_2O_8 + PbCl_2$; *Hedyphane*, $3(Pb, Ca)_3As_2O_8 + (PbCa)Cl_2$. Before the blowpipe on charcoal, the former completely, the latter partially, reduced to metallic lead, with evolution of arsenic fumes. If mimetite is fused, on cooling it crystallizes like pyromorphite.

Pyromorphite, see par. 263.

Minium, see par. 257; **Crocoite,** see par. 260; *Phœnicochroite*, $Pb_3Cr_2O_9$; *Dechenite* $(Pb,Zn)V_2O_6$. Crocoite and phœnicochroite give the chromium reaction (par. 84). Dechenite gives to the borax bead an emerald-green color, which becomes light olive-green in the oxidizing flame, then yellow and colorless. These three, on being boiled with a large amount of hydrochloric acid and for a long time, give an emerald-green solution, with separation of lead chloride; on adding alcohol to the liquid, concentrating by heat, pouring off from the residue, and then adding water, the liquid assumes a sky-blue color if dechenite is present; if the other minerals, green. The streak of crocoite and dechenite is reddish-yellow, and that of phœnicochroite brick-red.

Linarite, $PbCuSO_5 + aq$, is characterized by its deep azure-blue color. The color is destroyed by digesting with nitric acid, and lead sulphate is precipitated. In the closed tube gives off water.

Cerussite, see par. 265; *Phosgenite*, see par. 267;

Leadhillite, see par. 266; *Susannite*, $PbSO_4 + 3PbCO_3$, is of similar composition, but is hexagonal; *Lanarkite*, $PbCO_3 + PbSO_4$. All soluble in nitric acid, *with effervescence;* leadhillite and lanarkite leave an insoluble lead residue. The solution of phosgenite gives, with silver nitrate, a precipitate of silver chloride.

Mendipite, $Pb_3O_2Cl_2$. Very perfect prismatic cleavage; colorless, white. *Matlockite*, Pb_2OCl_2. Imperfect cleavage; green to yellowish-white. Dissolve in nitric acid *without effervescence;* the solution gives a precipitate with solution of silver nitrate.

Anglesite, $PbSO_4$, see par. 259.

Wulfenite, $PbMoO_4$, see par. 262.

Stolzite, $PbWO_4$. Color yellow, yellowish-brown to red; lustre resinous. Soluble in abundant quantity of hydrochloric acid, leaving a yellowish-green residue of WO_3. With sulphuric acid the pulverized mineral assumes a bright lemon-yellow color. The acid is not colored.

Vauquelinite, $Pb_2CuCr_2O_9$, see par. 261; *Vanadinite*, $3Pb_3V_2O_8 + PbCl_2$. Hexagonal. Color of the former blackish to olive-green; of the latter, brown or yellowish. Both impart to the borax bead an emerald-green color; both are soluble in nitric acid. The solution of vanadinite is yellow, and gives a precipitate with silver nitrate; that of vauquelinite not. *Descloizite*, $Pb_2V_2O_7$, same as vanadinite, but trimetric.

Compare *Plumbogummite*, par. 264.

Laxmannite, $(Pb,Cu)_6(P,Cr)_4O_{17}$. Pistachio to olive-green; lustre vitreous. Dissolved in nitric acid, ammonium molybdate gives a yellow precipitate (*phosphoric acid*).

Division 3. **When moistened with hydrochloric acid, color the flame blue, and give with nitric acid a solution which, on addition of an excess of ammonia, becomes azure-blue.**

The copper oxide minerals of this group are for the most part decomposed to such an extent by boiling with caustic potash that their acids combine with the potash.

Section 1. **Before the blowpipe on charcoal give a strong *arsenic* odor, and most yield a white brittle globule of copper arsenide. They are of green color.**

Chenevixite, $(Fe,Cu_3)_2As_2O_{11} + 3aq$. Lustre vitreous; color dark-green; streak yellowish-green. Fuses to a black magnetic slag, while the following do not:

Bayldonite, $(CuPb)_4As_2O_9 + 2aq$. Lustre resinous; color green. Dissolved in nitric acid, gives a precipitate with sulphuric acid of lead sulphate. In a closed tube gives off water and becomes black.

Olivenite, see par. 230; *Clinoclasite*, $Cu_6As_2O_{11} + 3aq$. Color dark bluish-green. In matrass gives 7 per cent. of water, and olivenite 4 per cent.

Tyrolite, see par. 231; *Chalcophyllite*, $Cu_8As_2O_{13} + 12aq$. Color emerald- to grass-green. Both decrepitate violently and yield much water; chalcophyllite dissolves in ammonia without leaving a residue. H. = **2.**

Conichalcite, $2(Cu,Ca)_4(As,P,V)_2O_9 + 3aq$. Color pistachio- to emerald-green. H. = **4.5.** Fused, gives an alkaline reaction.

Liroconite, $(Cu_3Al_2)(As,P)_2O_{11} + 12aq$. Color sky-blue to green; does not decrepitate in the matrass; changes to a smalt-blue color when gently heated; loses 22 per cent.

of water on ignition. Soluble in ammonia, with white flocky residue.

Euchroite, $Cu_4As_2O_9 + 7aq$; *Erinite*, $Cu_5As_2O_{10} + 3aq$. Color of both emerald-green. The former loses by ignition 19 per cent. of water; the latter only 5 per cent. Erinite amorphous. *Cornwallite*, $Cu_5As_2O_{10} + 3aq$, also amorphous. Loses 13 per cent. of water on ignition.

Section 2. Before the blowpipe on charcoal give *no arsenic* odor, but most yield a malleable copper bead.

Atacamite, see par. 226; *Tallingite*, $CuCl_2 + 4H_2CuO_2 + 4aq$, and *Percylite*, $(Pb,Cu)(Cl_2O) + aq$; *Nantokite*, CuCl. White; yields no water in a closed tube. **Chalcanthite**, see par. 229; *Brochantite*, $Cu_4SO_7 + 3aq$; **Covellite**, CuS. These three minerals give a sulphur reaction (par. 121); chalcanthite is soluble in water; the other two not. Color of covellite dark indigo-blue; of brochanthite, emerald- to blackish-green, with 12 per cent. of water. *Langite*, $Cu_3SO_6 + 4aq$; greenish-blue color, with 16 per cent. of water.

Cuprite, see par. 227; **Melaconite**, see par. 228. Both dissolve readily in acids without effervescence (except impure varieties of melaconite).

Malachite, see par. 232; **Azurite**, see par. 233; *Mysorin*, $CuCO_3$. Color blackish-brown, usually green or red from mixture with malachite or iron oxide; does not yield water in a matrass. All three dissolve readily in acids, with effervescence. *Aurichalcite*, $(Zn,Cu)_3CO_5 + 2aq$, gives a zinc coating on coal. Color bluish-green. *Atlasite*, $7Cu_2CO_4 + CuCl_2 + 10aq$, dissolved in nitric acid, gives a precipitate with silver nitrate. Celandine- to emerald-green.

Pseudomalachite, $Cu_6P_2O_{11} + 3aq$ (*Lunnite* and *Ehlite*), *Libethenite,* $Cu_4P_2O_9 + H_2O$. Dark olive-green. *Tagilite,* $Cu_4P_2O_9 + 3aq$. Verdigris- to emerald-green. Are all readily soluble in nitric acid without effervescence; the (slightly acid) solution gives a precipitate with lead acetate. Pseudomalachite loses 14 per cent. of water on ignition; the others less (from 7 to 10).

Torbernite, $CuU_2P_2O_{12} + 8aq$. Color grass-, leek-, to emerald-green. Dissolves in nitric acid to a yellowish-green liquid, on addition of ammonia in excess, a bluish-green precipitate is formed, the supernatant liquid being blue. Warmed with ammonium molybdate, gives a yellow precipitate.

Volborthite, $(Cu,Ca)_4,V_2O_9 + H_2O$. Olive-green to lemon-yellow. Pearly lustre; fuses easily. H. = 3–3.5.

Division 4. Before the blowpipe impart to the borax bead a sapphire-blue color (*cobalt*).

Erythrite, see par. 217; *Annabergite,* see par. 283; *Heterogenite,* $CoO + 2Co_2O_3 + 6aq$. Color black to reddish-brown; difficultly fusible. Colors the flame green.

Division 5. Fused in forceps, or on charcoal in reducing flame, give a black or gray metallic magnetic mass, but do not give the reactions of the preceding divisions.

To observe well the magnetic character of the fused mineral it is advisable to expose a pretty large assay-piece for some time to the action of the reduction flame.

Section 1. Evolve a strong arsenic odor during fusion.

Scorodite, see par. 253; *Pitticite,* $Fe_2O_3,As_2O_5,SO_3 +$

H_2O; *Pharmacosiderite*, $\dot{F}e_4As_6O_{27} + 15$ aq. Color and streak green, brown, yellow. H.= **2.5**. Subtransparent to subtranslucent; somewhat sectile; pyro-electric. *Beudantite*, $Fe_8As_2O_{17} + 15$ aq. The pulverized minerals assume with potassium hydrate a reddish-brown color. Scorodite and beudantite occur crystallized; the first trimetric and the second rhombohedral. Their color is usually some shade of green to brown and black. Streak greenish-gray to yellow; lustre vitreous. Pitticite, massive and reniform. H.= **2–3**. Lustre vitreous, sometimes greasy; color yellowish, brownish, blood-red, and white; streak yellow-white; translucent-opaque.

Arseniosiderite, $(Ca_3\dot{F}e)As_2O_8 + H_6\dot{F}eO_6$. Color yellowish-brown; fibrous; lustre silky.

Morenosite, $NiSO_4 + 7$ aq. Partly soluble in water. The solution assumes a blue color on addition of ammonia; sometimes contains arsenic.

Section 2. Soluble in hydrochloric acid without leaving a perceptible residue, and without gelatinizing. Give no arsenic odor when fused on coal.

Ludwigite, Mg,B,Fe,$\dot{F}eO_8$. Finely fibrous; blackish-green to black. Warmed with sulphuric acid and treated with alcohol, burns with a green flame.

Rabdionite, (Cu,Mn,Co)($\dot{F}e\dot{M}n$)O_4. In a closed tube yields 13 per cent. of water and colors the borax bead cobalt-blue. Color black. Solution in phosphoric acid, violet.

Stibioferrite, $Fe_2O_3,Sb_2O_5 +$ aq. Amorphous coating on stibnite; color yellow; gives on charcoal antimony fumes.

Pettkoite, $(Fe_3\dot{F}e)S_3O_{12}$, with little or no water. H.= **2.5**. Isometric; lustre bright; color pure black; streak

dirty-greenish. Soluble in water; precipitate with barium chloride.

Melanterite, see par. 251; *Botryogen*, $(Fe,Mg)FeS_4O_{16} + 12aq$. Melanterite and botryogen are soluble in water, the latter leaving a yellow residue. The solutions give precipitates with barium chloride; also with ammonia. Streak and color of melanterite are green; of botryogen, color ochre-yellow to red; streak yellow. *Rœmerite*, yellowish-brown. **Coquimbite,** *Jarosite*, and *Fibroferrite*, all yellow. The last, fibrous and silky, behaves similarly to botryogen. Belonging to this section are **Copiapite,** *Raimondite*, *Pastreite*, *Carphosiderite*, all giving a yellow powder, and are *insoluble* in water. *Voltaite* is distinguished from the foregoing by its black or dark-green color, resinous lustre, and octahedral crystallization. All these sulphates, when heated in the closed tube, give much water.

Siderite, see par. 254.

Hureaulite, $(Mn,Fe,H_2)_3P_2O_8 + 4aq$. H.=**5.** **Triplite** $(Fe,Mn)_3P_2O_8 + (Fe,Mn)F_2$. H.=**4.5–5.** Fuse readily; moistened with sulphuric acid, give the phosphoric acid reaction (par. 60); with borax, strong manganese reaction; hureaulite yields much water; triplite none, or very little.

Sarcopside, $4(Mn,Fe)_3P_2O_8 + H_4FeO_5$, distinguished from triplite by its color — flesh-red to lavender-blue; streak straw-yellow; lustre silky. H.=**4.**

Triphylite, $(Fe,Mn,Li_2)_3P_2O_8$, shows a similar behavior; the manganese reaction is much less decided. On dissolving the mineral in hydrochloric acid, evaporating the solution to dryness, adding alcohol, heating the alcohol to ebullition, and burning the vapor, the flame assumes a purple color. Color greenish-gray to bluish; cleavage

perfect; resinous lustre. H.=5. *Zwieselite*, a clove-brown variety.

Diadochite, Fe_2O_3,P_2O_5,SO_3,H_2O. H.=3; G.=2.03. Reniform or stalactitic; lustre resinous to vitreous; color yellowish-brown; streak uncolored; soluble in hydrochloric acid; gives precipitate with barium chloride; when ignited, gives off sulphuric acid.

Vivianite, see par. 252; *Dufrenite* (*Kraurite*), $Fe_4P_2O_{11} + 3aq$; **Cacoxenite,** $\dot{F}e_2P_2O_{11} + 12aq$; *Borickite*, $(\dot{F}eCa_3)_5P_4O_{25} + 15aq$. Fuse readily and behave with sulphuric acid like the preceding; give no manganese reaction. Yield much water in a matrass: cacoxenite, 33 per cent.; vivianite, 28 per cent.; borickite, 19 per cent.; dufrenite, 10 per cent. Color of dufrenite, leek-green; of cacoxenite, ochre-yellow; of vivianite, various shades of blue; of borickite, reddish-brown. *Beraunite*, $\dot{F}eP_2O_8 + aq$, is a similar phosphate of red color.

Hematite, see par. 244.
Compare *Limonite*.

Section 3. With hydrochloric acid gelatinize, or are readily decomposed with separation of silica.

Cronstedite, $(3FeMg)_2SiO_4 + \dot{F}e_2SiO_8) + 6aq$. H.=3.5. Rhombohedral, also amorphous; color black; streak dark leek-green; gelatinizes with hydrochloric acid. In a closed tube gives off water; fuses with puffing to a black glass. *Sideroschisolite* is probably a variety.

Stilpnomelane, $(FeMg)_2(\dot{F}e,\dot{A}l)Si_5O_{15} + 3aq$. H.=3.4. **Chalcodite** is similar in composition, often of velvety coatings of brass-like lustre. The color of these minerals is black, yellowish, and greenish-brown; their streak is greenish-gray.

Voigtite, *Ekmannite*, and *Euralite* are closely related to the above. The first are mica-like in aspect and structure, and the last is massive and yields 11 per cent. of water. Is decomposed by hydrochloric acid without gelatinizing.

Palagonite, of brownish-yellow color and streak; amorphous; yields water (14 per cent.) and fuses to a black magnetic glass. Some varieties gelatinize; others do not. See also *Follyte*.

Ilvaite, $H_2Ca_2Fe_4FeSi_4O_{18}$; **Allanite**, $(Ce,La,Di,Fe,Ca)_3(AlFe)Si_3O_{12}$, yield no water, or only a trace; gelatinize with hydrochloric acid; allanite fuses with intumescence to a voluminous brownish or blackish glass; ilvaite intumesces but slightly, decrepitates, and fuses to an iron-black bead. Hardness of each, **5.5–6.**

Fayalite, Fe_2SiO_4, and **Hortonolite**, $(Fe,Mg)_2SiO_4$, are crystalline, cleavable, gelatinize perfectly, of resinous lustre, and H. = **6.5.** Color of fayalite is black, greenish, or brownish-black; easily fusible and magnetic. Hortonolite, decomposed by phosphoric acid, the jelly treated with nitric acid, immediately becomes violet.

Knebelite, $(FeMn)_2SiO_4$, shows the same reaction. Color gray, red, brown to black; easily fusible. H. = **6.5.**

Roepperite, $(Fe,Mn,Zn,Mg)_2SiO_4$. Color dark-green to black, difficultly fusible, and gives with soda a sublimate of zinc oxide.

Pyrosmalite, $(FeMn)Cl_2 + 7(Fe,Mn)SiO_3 + 5\,aq$, and *Astrophyllite*, $(K,Na)_6(Fe,Mn)_{15}(FeAl)_2(Si,Ti)_{16}O_{56}$, containing titanium, and sometimes zirconium, are decomposed by hydrochloric acid, with separation of silica, without gelatinizing. Fusibility **2–2.5.** Pyrosmalite gives the chlorine reaction (par. 65); astrophyllite not. The hy-

drochloric acid solution of the latter gives the reaction for titanic acid. Both minerals are cleavable in one direction; the latter often micaceous.

Lepidomelane, $K_4Fe_2(\cancel{Al}Fe)_3Si_6O_{24}$. H.=3. Lustre vitreous; color dark-green to black, with occasionally a leek-green reflection; streak grayish-green; micaceous. Easily decomposed by hydrochloric acid, depositing silica in scaly flakes; easily fusible.

Allochroite, $Ca_3\cancel{Fe}Si_3O_{12}$. Some varieties form an imperfect jelly with hydrochloric acid. Not cleavable; color green, brown, black; lustre greasy.

Gillingite, $\cancel{Fe}O_3$,FeO,MgO,CaO,SiO_2,H_2O; *Xylotile*, $\cancel{Fe}O_3$,MgO,SiO_2,H_2O [a variety of *Serpentine*], fuse with difficulty; do not gelatinize. The former is black, amorphous; the latter brown, fibrous, woody. Both yield water in a matrass.

Some impure varieties of **Limonite,** see par. 248.

Section 4. But little affected by hydrochloric acid.

Crocidolite, Na,Mg,Fe.,SiO_2 + H_2O, and *Arfvedsonite*, 2(Na_2,Fe,Ca)SiO_3 + $Fe_2Si_3O_9$, are easily fusible (1.7–2), with much intumescence and escape of gas, bubbles to a black glass. Color of crocidolite, lavender-blue or leek-green; fibrous; yields water in a matrass; arfvedsonite is black and yields no water.

[See also *Hornblende* and *Tourmaline*, some varieties of which become slightly magnetic after fusion; and also *Lepidomelane.*]

Glauconite, FeO,MgO,K_2O,Al_2O_3,SiO_2,aq [green earth]. Fusibility 3, without swelling, and gives water in the matrass; color celandine-green; hardness 1; earthy.

Acmite, ($Na_6Fe_3\cancel{Fe}$)Si_3O_9; *Babingtonite*, 9(Ca,Fe,Mn)SiO_3 + $\cancel{Fe}Si_3O_9$. Fusibility of the former 2; of the lat-

ter, 2.5. Form a black lustrous slag. Acmite cleaves at an angle of 93°. Babingtonite, fused with soda, dissolved in hydrochloric acid, and ammonia added to separate iron, the filtrate with ammonium oxalate, gives a heavy precipitate of lime. Acmite gives no lime precipitate.

Compare *Augite.*

Almandine Garnet [iron garnet], $Fe_3Al_2Si_3O_{12}$. Fuses quietly at 3; gelatinizes after fusion; hardness 7–7.5; color reddish-brown; not very cleavable. See also *Allochroite.*

Wolframite, $(Fe,Mn)WO_4$. Color brownish-black; streak brownish; sub-metallic lustre. Boiled with concentrated phosphoric acid, a blue syrup, which, diluted with water, becomes colorless; if powdered iron is added and then shaken, it gives a fine blue color. Decomposed with aqua regia, with separation of a yellow powder, WO_3.

Megabasite, $Mn,FeWO_4$, behaves in a similar manner. Streak ochre-yellow. *Hübnerite,* Mn,WO_4, same reactions, but contains no iron.

Rhodonite, see par. 275.

Lepidolite, $(K,NaLi)_6Al_4Si_{12}O_{39}$. Color rose-red to gray-white; fracture often micaceous; lustre vitreous. H. = 2.5–3; fusibility 2–2.5. Often becomes magnetic, and colors the flame reddish-purple.

Compare *Lepidomelane,* p. 250.

Division 6. Not belonging to either of the preceding divisions.

Molybdite, MoO_3. Color sulphur- or orange-yellow; earthy. H. = 1–2; fusibility = 1. Gives with the fluxes the reactions of molybdic acid. Dissolves readily in hydrochloric acid; the solution is colorless, but turns blue on being shaken with tin foil. Fuses on coal, fumes, and

is absorbed. With salt of phosphorus in the reducing flame, gives a bead, when cold, of beautiful green.

Eulytite, $Bi_4Si_3O_{12}$. H. = 4.5. Fuses easily to a brown bead; gelatinizes with hydrochloric acid; on charcoal, with soda, yields a globule of metallic bismuth; color dark-brown to yellow; lustre resinous.

Bismutite, see par. 211; *Pucherite*, $BiVO_4$. H. = 4. Fuses easily; vitreous, adamantine lustre. With salt of phosphorus gives a green bead in the reducing flame. These three minerals give the bismuth reaction with potassium iodide and sulphur on charcoal.

Compare *Walpurgite*, p. 256; compare also *Allanite* of the previous division; also *Lepidomelane*, p. 250.

PART II. Fused with soda on charcoal give no metallic globule, or, fused alone in reducing flame, no magnetic metallic mass.

Division 1. After fusion and continued heating on charcoal, in the forceps or on platinum foil, have an alkaline reaction, and change the color of moistened turmeric paper to reddish-brown. The test may be made with splinters, and not with the powder.

Section 1. Easily and completely soluble in water.

Nitre, KNO_3; **Soda Nitre**, $NaNO_3$, deflagrate vividly on burning coals. Fused on platinum wire, the former colors the flame bluish, with a red tint; the latter, bright-yellow. Platinum chloride gives a precipitate with a solution of nitre.

Natron, $Na_2CO_3 + 10aq$; **Trona**, $Na_4C_3O_8 + 3aq$. The aqueous solution has an alkaline reaction, and effervesces on addition of hydrochloric acid. Crystals of the

former decompose quickly in the air; the latter not. *Thermonatrite*, Na_2CO_3, + aq. H. = **1.5**. Effloresces in the air, and behaves like the preceding.

Mirabalite, $Na_2SO_4 + 10aq$; *Thenardite*, Na_2SO_4; *Aphthitalite*, K_2SO_4: **Epsomite**, $MgSO_4 + 7aq$; **Kalinite**, $K_2AlS_4O_{16} + 24aq$. The aqueous solutions of these minerals do not effervesce with acids; give a copious precipitate with barium chloride; the solutions of kalinite and epsomite are precipitated by potassium carbonate (distinguished by reaction with cobalt solution, par. 44). *Kainite*, $K_2MgS_2O_8 + 6aq$, behaves in a similar manner; soluble in water, and a precipitate is formed with silver nitrate. The concentrated solution of aphthitalite gives a precipitate with platinum chloride; mirabalite yields much water; thenardite none; the epsomite contains 50 per cent. of water; *Loeweite*, $2Na_2MgS_2O_8 + 5aq$, and *Kieserite*, $MgSO_4 + aq$, each 14 per cent.; *Bloedite*, $Na_2MgS_2O_8 + 4aq$, 21 per cent.; and kainite, 27 per cent. *Picromerite*, $K_2MgS_2O_8 + 6aq$.

Tachydrite, $CaMg_2Cl_6 + 12aq$. Color yellowish; deliquescent; yields much water in the matrass; colors the flame red. *Carnallite*, $KMgCl_4 + 6aq$. Massive, granular; lustre greasy; color milk-white; often reddish from presence of iron oxide; strongly phosphorescent; yields much water; fuses easily; easily soluble in water; and yields precipitate with platinum chloride.

Halite, NaCl; **Sylvite**, KCl. The aqueous solution gives a copious precipitate with silver nitrate; gives also the reactions for chlorine described in pars. 65, 66. The latter gives a heavy yellow precipitate with platinic chloride, but the former does not.

Borax, $Na_2B_4O_7 + 10aq$, gives the reaction for boric acid (pars. 75, 76).

Section 2. Insoluble in water, or difficultly soluble.

Ulexite, $NaCaB_5O_9 + 5aq$. Fusibility 1, coloring the flame yellow; yields much water. Moistened with sulphuric acid, the flame changes momentarily to green. Somewhat soluble in hot water, giving alkaline reaction.

Gay-Lussite, $Na_2CO_3 + CaCO_3 + 5aq$; **Witherite,** $BaCO_3$; *Staffelite,* $Ca_3P_2O_8 + CaCO_3$. Dissolve in dilute hydrochloric acid with effervescence; the first yields water; the latter do not. The solution of the staffelite gives a precipitate with ammonia (calcium phosphate); the others not. The solution with ammonium molybdate, warmed, gives a yellow precipitate.

Compare *Strontianite,* which colors the flame crimson.

Anhydrite, $CaSO_4$; **Gypsum,** $CaSO_4 + 2aq$; **Polyhalite,** $Ca_2MgK_2S_4O_{16} + 2aq$; *Glauberite,* $Na_2CaS_2O_8$. Soluble in much hydrochloric acid; in the solution barium chloride gives a heavy precipitate; gypsum yields much water; polyhalite little; the rest none; anhydrite is distinguished by superior hardness, 3.5; polyhalite is distinguished from glauberite by its solution giving a yellow precipitate with platinum chloride.

Syngenite, $K_2CaS_2O_8 + aq$, which occurs in halite, is similar to polyhalite.

Barite, $BaSO_4$; **Celestite,** $SrSO_4$. Insoluble in hydrochloric acid; give a sulphur reaction when treated as described in par. 121. Celestite colors the flame red (par. 59); barite, yellowish-green (par. 60).

Fluorite, CaF_2; **Cryolite,** Na_6AlF_{12}; *Pharmacolite,* $2HCaAsO_4 + 5aq$. Do not effervesce with acids, and give no sulphur reaction. Pharmacolite evolves arsenical odor on charcoal; the other two give fluorine reaction (par. 76). Fusibility of fluorite, 3; of cryolite, 1. *An-*

tozonite (var. of fluorite), gives odor of antozone on being rubbed. *Chiolite*, Na_3AlF_9, behaves like cryolite; occurs only massive-granular; while cryolite is distinctly crystalline, and cleavable in three directions.

Pachnolite, $Na_2Ca_2AlF_{12}2aq$, yields strongly acid water. Closely related are *Arksutite* and *Chodneffite*, without water; and *Gearksutite*, with water.

Cancrinite, $Na_2AlSi_2O_8$, effervesces with hydrochloric acid, and gelatinizes. In the flame it grows white and opaque, and then melts (2.5), intumesces, and forms a white blebby mass. The easy fusibility distinguishes it from nephelite, which, laid on turmeric paper and moistened, gives an alkaline reaction.

Division 2. Soluble in hydrochloric acid without leaving a perceptible residue; some also soluble in water; not gelatinized by evaporation.

(Compare those of the former division which give only a weak alkaline reaction after fusion—*Kieserite*, *Kainite*, *Epsomite*.)

Durangite, fuses very easily; gives arsenic and fluorine reactions. Orange-red; streak yellowish.

Tschermigite, $(NH_4)_2AlS_4O_{16} + 24aq$; *Alunogen*, $AlS_3O_{12} + 18aq$; *Goslarite*, $ZnSO_4 + 7aq$. Fuse when first heated, and swell up to an infusible mass. All soluble in water; give sulphur reaction (par. 121). Heated on charcoal and treated with solution of cobalt, the former assume a blue, the latter a green, color (pars. 53, 54). The first, with caustic potash, gives the smell of ammonia; the second does not.

Chondrarsenite, $Mn_6As_2O_{11} + 3aq$, easily fusible, giving arsenic fumes on charcoal, and amethyst color to the borax bead. Color yellow.

Walpurgite, $Bi_{10}U_3As_4O_{34} + 12aq$; *Trögerite*, $U_3As_2O_{14} + 12aq$, give a green bead with salt of phosphorus, and the first gives the bismuth reaction with potassium iodide and sulphur.

Fauserite, $(Mn,Mg)SO_4 + 6aq$. Soluble in water; heated with phosphoric and nitric acids, gives a violet solution. Contains 40 per cent. of water.

Adamite, $Zn_4As_2O_9 + aq$, easily fusible, giving arsenic fumes on charcoal, with a coating of zinc. Color honey-yellow.

Struvite, $NH_4MgPO_4 + 12aq$, melts easily; yields water in matrass; with caustic potash, ammonia; and with hydrochloric acid, fumes of ammonium chloride. *Sussexite*, $(Mn,Mg)_2B_2O_5 + aq$. H. = 3. Fibrous; silky; gives a violet bead with borax.

Sassolite, H_3BO_3; **Boracite**, $Mg_7B_{16}Cl_2O_{30}$; *Hydroboracite*, $CaMgB_6O_{11} + 6aq$. Give the boric acid reaction (par. 75). Sassolite is soluble in alcohol; the others not; boracite yields no water, while the others do. Hydroboracite contains 26 per cent. water, and a similar mineral, *Szaibelyite*, $Mg_5B_4O_{11} + 3aq$, 7 per cent. *Lüneburgite*, $Mg_3P_2B_2O_{11} + 8aq$. Its nitric acid solution gives a yellow precipitate with ammonium molybdate.

Alabandite, MnS, and *Hauerite*, MnS_2, give strong manganese reaction (see par. 273).

Wagnerite, $MgF_2 + Mg_3P_2O_8$; **Apatite**, $3Ca_3P_2O_8 + Ca(Cl,F)_2$. Moistened with sulphuric acid, impart a pale bluish-green color to the flame. Fusibility of wagnerite, 3–3.5 (with intumescence); of apatite, 5 (without intumescence); wagnerite is soluble in dilute sulphuric acid; apatite not. *Hebronite* is similar, and contains 4 per cent. of water.

Brushite, $HCaPO_4 + 2aq$, behaves in the wet way like

apatite, but yields 26 per cent. water. *Isoclasite*, $Ca_4P_2O_9 + 5aq$.

Amblygonite, $2AlP_2O_8 + 3(LiNa)F$. Fusibility 2; hardness 6. With difficulty soluble in concentrated sulphuric or hydrochloric acid. *Kjerulfine*, $2Mg_3P_2O_8 + CaF_2$.

Torbernite, $CuU_2P_2O_{12} + 8aq$; *Autunite*, $CaU_2P_2O_{12} + 10aq$. Fuse readily, yield water, and give, with fluxes, the reactions of uranium sesquioxide (see Table II.). Soluble in nitric acid. The first gives a globule of copper with soda on coal. See Div. 3, p. 245.

Division 3. Soluble in hydrochloric acid, forming a stiff jelly, especially after partial evaporation.

Section 1. Before the blowpipe in a matrass give water.

Datolite, $H_2Ca_2B_2Si_2O_{10}$, yields but little water, and gives the boric acid reaction (par. 60).

Edingtonite, $BaAlSi_3O_{10} + 3aq$. The dilute hydrochloric acid solution gives a precipitate with sulphuric acid of barium sulphate. Sp. gr. 2.7.

Natrolite, $Na_2Al_2Si_3O_{10} + 2aq$. Fusibility 2; does not intumesce; hardness 5–5.5.

Scolecite, $CaAlSi_3O_{10} + 3aq$; **Laumontite,** $Ca,AlSi_4O_{12} + 4aq$. Scolecite, on being heated, curls up like a worm, and finally melts to a bulky, shining slag, which in the inner flame becomes a vesicular, slightly-translucent bead; hardness 5.5; pyro-electric. Laumontite intumesces and fuses to a white translucent enamel; hardness 3.

Chalcomorphite, $CaO,Al_2O_3,SiO_2,H_2O,CO_2$, fuses in very fine splinters with difficulty, and curls up like scolecite.

Nearly related to scolecite, and showing a similar be-

havior, are — *Mesolite*, $(Ca,Na_2)\dot{A}lSi_3O_{10} + 3aq$. H.= 5; G.= 2.3; white, fibrous, and silky; and *Thomsonite*, $2(Ca,Na_2)\dot{A}lSi_2O_8 + 5aq$. H.= 5; G.= 2.35; prismatic and vitreous; but they are not pyro-electric.

Phillipsite, $(CaK_2Na_2\dot{A}lSi_4O_{12}, + 4aq$, 4.5. Fusibility 3, with slight intumescence; occurs always in twin crystals; lustre vitreous; color white; sometimes reddish. *Gismondite*, $(Ca,K_2)Al_2Si_3O_{10} + 4aq$, is closely related. Trimetric, with forms often resembling square octahedrons. H. = 4.5. Lustre splendent. *Ittnerite*, $\dot{A}lO_3,CaO,Na_2O,H_2O,SO_3SiO_2$. Ash-gray color; vitreous lustre. Fuses with intumescence, and differs from the above in giving a precipitate in the hydrochloric acid solution with barium chloride.

Compare, in Div. 4, *Apophyllite*, *Okenite*, and *Analcite*, which gelatinize with hydrochloric acid, 260.

Section 2. Before the blowpipe give no water, or only traces.

(Compare *Datolite*, of the foregoing division.)

Helvite, $3(Be,Mn,Fe)_2SiO_4 + (Mn,Fe)S$; **Tephroite**, Mn_2SiO_4. Distinguished from the other minerals of this section by giving manganese reactions. Color of helvite, wax-yellow; hardness 6–6.5; of tephroite, ash-gray; hardness 5.5–6. *Danalite*, $3(Be,Mn,Fe,Zn)_2SiO_4 + (Fe,Mn,Zn)S$, containing zinc, gives, with soda on coal, a small slag of zinc, and with borax the iron reaction. Color flesh-red to gray.

Compare *Willemite*, par. 303.

Hauynite, $2(Na_2,Ca)\dot{A}lSi_2O_8 + (Na_2,Ca)SO_4$, and *Lapis-Lazuli*, $CaO,Na_2O,\dot{A}lO_3,S,SiO_2$, are of azure-blue color; give sulphur reaction (par. 121). Fusibility of

the former, **4.5**; of the latter, **3**, forming a white glass.

Nosite, $2Na_2AlSi_2O_8 + Na_2SO_4$, and *Scolopsite*, AlO_3, $CaO,Na_2O,SO_3,Cl,SiO_2,H_2O$, of gray or brownish color; give sulphur reaction (par. 121). Fusibility of nosite, **4.5**; of scolopsite, **3** (with intumescence like idocrase). The former crystallizes in dodecahedrons; the latter occurs granular-massive.

Sodalite, $3Na_2AlSi_2O_8 + 2NaCl$; *Eudialyte*, $6Na_2(Ca, Fe)_2(Si,Zr)_6O_{15} + NaCl$, give the chlorine reaction (par. 82). In the nitric acid solution, silver nitrate gives a precipitate. The former fuses to a transparent, colorless glass; the latter to a pistachio-green scoria or opaque glass. The dilute hydrochloric solution of eudialyte colors the turmeric paper orange-yellow; boiled with potassium sulphate and evaporated to crystallization, and then boiled with water, a precipitate of zirconia is formed, which makes the solution cloudy. Sodalite, H. = **5.5–6**; G. = **2.3**; eudialyte, H. = **5.5**; G. **2.9**.

Wollastonite, $CaSiO_3$, fuses quietly to a colorless, semi-transparent glass. The hydrochloric acid solution gives no, or only a very slight, precipitate with ammonium hydrate, but with the carbonate a bulky precipitate. See also *Pectolite*.

Nephelite, $(Na,K)_2AlSi_2O_8$.

Melilite, $(Na_2Ca,Mg)_{12}(AlFe)_2Si_9O_{36}$.

Meionite, $Ca_6Al_4Si_9O_{36}$.

With the solution of these minerals in hydrochloric acid, ammonia gives a precipitate. Meionite fuses, with intumescence, to a vesicular glass, which is not completely rounded by fusion. The others fuse quietly. The solution of melilite, after the separation of alumina with ammonium hydrate, gives a strong precipitate with am-

monium oxalate, while the solution of nephelite, treated in the same manner, gives no precipitate, or a very slight one. Nephelite hexagonal; melilite dimetric. *Elæolite*, a variety of nephelite, has a greasy lustre. Compare *Cancrinite*. The behavior of *Barsowite*, Ca,Al,Si_2O_8, is similar to melilite, but fuses with more difficulty, and quietly. F. = 4.

Compare *Gehlenite*, Div. 5, p. 283, which is nearly infusible; *Tachylite*, Div. 5, p. 263; and *Willemite*, Div. 2, p. 276.

Division 4. Soluble in hydrochloric acid, with separation of silica, without forming a perfect jelly.

(It is sometimes necessary to treat the finely-pulverized mineral with concentrated acid.)

Section 1. Before the blowpipe in a matrass give water.

Klipsteinite, MnO_3,MnO,SiO_2,H_2O, easily decomposed by hydrochloric acid, evolving chlorine; and silica separates as a slimy powder. Fuses to a black slag in the oxidizing flame. With phosphoric acid it gives a violet solution. By ignition gives 9 per cent. of water.

Apophyllite, $4(H_2CaSi_2O_6 + aq) + KF$; **Pectolite**, $HNaCa_2Si_3O_9$; *Okenite*, $H_2CaSi_2O_6 + aq$. The silica separates in the shape of gelatinous lumps. After the separation of the silica, the hydrochloric acid solution gives no, or only a slight, precipitate with ammonia Pectolite fuses to an enamel-like glass, with slight intumescence, and yields but little water; the others much. Fusibility of apophyllite, 1.5, forming a white vesicular glass; of okenite, 2.5–3; fuses with frothing, forming a porcelain-like mass.

Compare *Xonaltite* and *Sepiolite*, Div. 5, pp. 281, 282.

Analcite, $Na_2\overline{A}lSi_4O_{12} + 2aq$, gelatinizes like the preceding, in some varieties forming a perfect jelly. After the separation of the silica of the acid solution, ammonia produces a copious precipitate. Before the blowpipe, with the first action of the flame, it becomes opaque, but fuses quietly to a perfectly clear glass. The crystals are usually traperohedrons and cubes; not cleavable; yields 8 per cent. of water.

Pyrosclerite, $Mg_{12}\overline{A}l_2Si_9O_{36} + 12aq$; *Chonicrite*, $(CaMg)_{10}\overline{A}l_2Si_7O_{30} + 6aq$; *Jollyte*, $(FeMg)_6Al_8Si_9O_{36} + 12aq$, are distinguished from the other minerals of this section by their inferior hardness, **2.5–3.** Chonicrite fuses from **3.5–4,** with intumescence; has no cleavage; whitish; yields 9 per cent. of water. Fusibility of pyrosclerite, **4,** without intumescence; cleavable in one direction; green; yields 11 per cent. of water. Jollyte fuses with difficulty; amorphous; brown; powder light-green.

Of similar constitution as pyrosclerite are—*Vermiculite*, $(Mg,Fe)_{12}\overline{A}l_2Si_9O_{36} + 12aq$, and *Jefferisite*, $Mg_4(\overline{A}l,\overline{F}e)_2Si_5O_{20} + 6aq$. They are both of brownish-yellow color, micaceous structure, pearly lustre, and before the blowpipe exfoliate remarkably; the former in worm-like forms.

Dudleyite, *Kerrite*, *Maconite*, *Wilcoxite*, and *Vaalite* belong with this section.

Brewsterite, $(Sr,Ba)AlSi_6O_{16} + 5aq$, characterized by its hydrochloric acid solution giving a precipitate with sulphuric acid. It fuses with frothing and intumescence. Fusibility **3,** and yields 13 per cent. of water.

Stilbite, $(Ca,Na_2)\overline{A}lSi_6O_{16} + 6aq$; *Hypostilbite*, $(Ca,Na_2)_2\overline{A}l_2Si_9O_{26} + 12aq$; **Chabazite,** $(H,K)_2Ca\overline{A}lSi_5O_{15} + 6aq$; **Prehnite,** $H_2Ca_2\overline{A}l_2Si_3O_{12}$. Fuse, with intumescence, to enamel-like masses. Prehnite yields but little water, losing by ignition only 4.3 per cent.; the others

lose from 15 to 20 per cent. Chabazite is distinguished by its rhombohedral crystallization and imperfect cleavage. In stilbite and hypostilbite the cleavage is perfect in one direction. Stilbite is trimetric, and hypostilbite occurs in radiate-fibrous or columnar masses. *Mordenite*, $(Ca,Na_2)AlSi_9O_{22}+6aq$. H. = 5; occurs in hemispherical, reniform, or cylindrical concretions, with a fibrous structure; yields 12 per cent. water, and fuses without intumescence.

Mosandrite, $CeO,LaO,DiO,CaO,Na_2O,TiO_2,SiO_2,H_2O$, and *Catapleiite*, $(Na_2Ca)(Si,Zr)_4O_9+2aq$, have hardness 4–4.5, and distinct cleavage. The first fuses with intumescence, then quietly to a yellowish-brown glass; fusibility 2.5–3; catapleiite, 3; fuses quietly, giving a white porcelain bead. It is soluble in hydrochloric acid without gelatinizing, and gives the zirconia reaction, coloring turmeric paper orange-yellow. If boiled with potassium sulphate nearly to dryness, and water added, it gives a precipitate of zirconia. Mosandrite gives no precipitate; it contains 9 per cent. of water. Mosandrite, with salt of phosphorus in reducing flame, gives a violet color (*titanic acid*).

Sepiolite [meerschaum], $Mg_2Si_3O_3+2aq$. See below. **Deweylite**, $Mg_4Si_3O_{10}+5aq$. Distinguished by being much less fusible than the preceding; fusibility 5. The former absorbs water with great avidity; the latter not. Sepiolite contains 10 per cent. of water, and deweylite 20 per cent.

Sordawalite, AlO_3,FeO,MgO,SiO_2,H_2O. Amorphous; fusibility 2.5, forming a thick, black, brilliant glass; color brownish-black. Decomposed by hydrochloric acid with difficulty. The solution gives a greenish-gray precipitate with ammonia. It contains 4 per cent. of water.

Section 2. Before the blowpipe in a matrass give no water, or only traces.

(Compare *Pectolite*, *Chonicrite*, and *Prehnite*, of the preceding section.)

Many specimens of lapis-lazuli do not form a complete jelly, but may be recognized by their blue color.

Cryophyllite, $(K,Li)_{12}Fe_3(Al,Fe)_4Si_{21}O_{63}$. Micaceous; fuses easily in the flame of a candle, giving the flame a lithia reaction.

Tachylyte, $Na_2O,CaO,MgO,FeO,Al_2O_3,SiO_2H_2O$, fuses easily (**2.5**) and quietly to a black shining glass. Hardness **6.5**; color black. Decomposed with hydrochloric acid, the silica separates in lumps. The solution, boiled with tin, does not become violet, which is the case with the two following minerals:

Schorlomite, $Ca_9Fe_2(Si,Ti)_{12}O_{39}$, and *Tscheffkinite*, CeO,FeO,CaO,TiO_2SiO_2. Fusibility **3–4**. The first fuses quietly, the second with much effervescence, to a black glass or a grayish mass. The first is decomposed with difficulty by hydrochloric acid, and the silica separates as a slimy powder; the second is easily decomposed, and the silica separates in gelatinous lumps. Color of both black; powder gray.

Ivaarite is similar to schorlomite.

Wernerite, $(Ca,Na_2K_2)Al_2Si_2O_8$, and *Porcellanite*, $SiO_2 Al_2O_3,CaO,Na_2O,Cl_2$, fuse easily at **2.5**, with intumescence, to a white vesicular glass, which is not easily rounded. They are quite cleavable in two directions. With wernerite belong *Nuttalite*, *Glaucolite*, and *Stroganovite*.

Wöhlerite, $CaO,Na_2O,SiO_2ZrO_2Cb_2O_5$, fuses easily at **3** to a light-green, very blebby glass. Decomposed with hydrochloric acid, with separation of silica in flocks; the

solution, strongly boiled with tin, becomes a beautiful blue (*columbium*), and on the addition of water, a blue filtrate. This solution colors turmeric paper orange-yellow. The mineral is wine-yellow, honey-yellow, or brownish-red. *Eucolite* probably belongs here.

Labradorite, $(Ca,Na_2)AlSi_3O_{10}$, and **Anorthite,** $Ca,AlSi_2O_8$, fuse quietly, without intumescence, forming a thick colorless glass. Hardness of the former, **6**; of the latter, **6–7**. Anorthite fuses with more difficulty (**4.5**) than labradorite (**3.5**). Labradorite cleaves in two directions with an angle of 94°, and on the perfect cleavage planes shows striæ, on the others none, and frequently a play of colors, blue and green, also red and yellow. Anorthite has perfect cleavage at an angle of 94° 12′. The labradorite is not wholly decomposed with hydrochloric acid.

Grossularite [some varieties]. Fusibility **3**; not cleavable.

Titanite [sphene] (Div. 6, p. 269), some varieties, see below. Gives titanium reactions (par. 125). See *Danburite*, Div. 6, p. 265, which gives a fine green flame; also *Tephroite*, Div. 3, p. 258. which gives an amethyst color to the borax bead.

Microsomnite, $(K_2Ca)Al_2Si_2O_8,CaSO_4,NaCl$. Colorless; vitreous; H. = **6**; Fus. = **5**; gives the chlorine reaction with copper oxide and salt of phosphorus.

Division 5. Little affected by hydrochloric acid. Before the blowpipe give an amethyst color to the borax bead (*manganese*).

Carpholite, $H_4Mn(AlFeMn)Si_2O_{10}$, occurs only in fibrous, radiated tufts. Color straw-yellow; silky; yields water, 11 per cent.; fusibility **2.5–3**.

Ardennite, of similar composition, with 9 per cent. of

VO_3; fibrous; stellated; of brownish-yellow color; yields water, 5 per cent.; fusibility **2.**

Spessartite [Manganese Garnet], $(Mn,Fe)_3AlSi_3O_{12}$. Color brownish-red; fuses without intumescence at **3**; not cleavable.

Piedmontite, $H_2Ca_4(MnFeAl)_3Si_6O_{26}$. Fusibility **2–2.5**; intumesces; cleavage quite distinct in one direction; less so in a second; color cherry-red to reddish-black.

Rhodonite, $MnSiO_3$. Fusibility **3**, without intumescence, when pure; color rose-red; cleavable (par. 275). It cleaves at an angle of 92° 55′. *Richterite* [manganese amphibole], cleaves at 124°.

Compare *Axinite*, p. 267.

Division 6. Not belonging to either of the preceding divisions. All are silicates except *Scheelite*, and are not decomposed, or only partially, by hydrochloric acid.

Danburite, $CaB_2Si_2O_8$. Fusibility **3**, and gives a fine green color to the flame (*boric acid*). The bead is clear while hot and cloudy when cold. Yields no water in the matrass. *Howlite*, $Ca_4B_{10}Si_2O_{23} + 5$ aq, is closely related, but yields water in the matrass.

Scheelite, $CaWO_4$. Fusibility **5**. Soluble in hydrochloric acid, leaving a greenish-yellow or lemon-yellow residue of tungstic acid, which is soluble in ammonia, and which gives, with salt of phosphorus, the characteristic reaction of tungstic acid (see Table II.). If the residue of tungstic acid is boiled with phosphoric acid till it begins to fume, after cooling a blue mass is formed, which gives a colorless solution with water. If iron filings be added to this and shaken for some time, it becomes intensely blue. G.=**6.**

Lepidolite, $(KLi)_6Al_8Si_{12}O_{39}$, and *Cookeite,* $(Li_2O,K_2O, Al_2O_3,SiO_2,H_2O)$, are micaceous, splitting very easily in one direction. Fusibility of lepidolite is **3,** colors the flame crimson, and gives little or no water in the matrass. Cookeite intumesces, colors the flame crimson, but yields much water in the matrass.

Gümbelite, SiO_2,Al_2O_3,K_2O,H_2O, occurs in short fibres. Before the blowpipe swells into a fan-shaped mass, fuses in thin fibres, and gives in the matrass 7 per cent. of water. Not attacked by hydrochloric or sulphuric acid.

Thermophyllite, $Mg_3Si_2O_7 + 2aq$, *Euphyllite,* $(AlNa_6 K_6)_6Si_9O_{36} + 4aq$, and **Margarite,** $H_2CaAl_4Si_2O_{12}$, are all micaceous in structure. The first intumesces before the flame and yields much water; the others fuse without intumescence (**4–4.5**) and yield little water. Their laminæ are not elastic. Euphyllite is easily decomposed by sulphuric acid, and margarite with difficulty.

Compare *Muscovite* and *Biotite.*

Petalite, $(Li_6Al_2)Si_6O_{15}$, and **Spodumene,** $(Li_6Al_2)Si_3O_9$, do not possess as perfect a cleavage as the preceding, and greater hardness (**6.5**). Specific gravity of petalite **2.4–3**; of spodumene, **3.1.** Both give the lithia reaction (par. 103). Spodumene fuses, with intumescence, to a clear or white glassy globule; petalite fuses quietly to a white enamel. *Castorite* belongs here, which alone gives a distinct red color to the flame.

Leucophanite, $4NaF + 3(CaBe)_4Si_3O_{10}$, fuses easily and quietly to a transparent colorless glass. Cleavage very marked in one direction. H. = **3.5–4.** If heated, phosphoresces with a reddish-violet light; also if struck with a hammer in the dark.

Wilsonite, $Al_2O_3,K_2O,MgO,SiO_2,H_2O$. Fusibility **2,**

swelling up to a whitish glass; yields water in a matrass; H. = 3; cleaves at right angles.

Nohlite. $Nb_2O_5, U_2O_3, YO, H_2O$, compact, brownish-black, fuses with difficulty, and gives in a matrass 4.5 per cent. of water; otherwise in chemical properties similar to samarskite.

Sordawalite. Fusibility **2.5**; amorphous; brownish-black. See Div. 4, p. 262.

Diallage, Ca, Mg, etc., SiO_2. Fusibility **3.5**; characterized by its pearly metallic lustre; cleaves easily in one direction.

Harmotome, $Ba, Al_2Si_5O_{14} + 5$ aq, distinguished from most of the other minerals of this division by yielding water in a matrass. In the partial solution in hydrochloric acid, sulphuric acid gives a precipitate with the barium. Occurs usually in twin crystals.

Axinite, $(Ca, Fe, K_2)_7(\text{~~Al~~}\,\text{Fe}\,\text{~~B~~})_3Si_8O_{32}$; **Tourmaline**, $\text{~~Al~~}O_3\,\text{~~B~~}O_3$, FeO, MgO, MnO, K_2O, Na_2O, Li_2O, SiO_2, F, give the reaction of boric acid (par. 61). Axinite fuses readily, with intumescence, to a dark-green glass. Different varieties of tourmaline show different blowpipe characteristics, but all are pyro-electric. Hardness of axinite and of tourmaline **6.5–7.5**. Heat does not develop electricity in axinite.

Pyroxene. General formula, $RSiO_3$. R may be Ca, Mg, Fe, Zn, Mn, K_2, Na_2(~~Al~~, Fe, ~~Mn~~). Two or more of these bases are usually present. Calcium is always present, and constitutes a large per cent. of the mineral. H. = 5–6; G. = 3.2–3.5. Monoclinic. Cleavable nearly at right angles of 93° and 87°. Occurs in thick, stout prisms; massive, granular, fibrous, and lamellar; color shades of green, white to brown or black, through *bluish* shades, but not *yellow;* lustre vitreous and somewhat pearly.

Varieties:

I. Light-colored. G.=3.3–3.4.

Malacolite, or *White Augite*, (Ca,Mg), white or grayish crystals and crystalline masses. *Diopside*, of the same composition, light- or grayish-green crystals; also massive, cleaving with a bright, smooth surface. *Sahlite*, (Ca,Mg,Fe), grayish- or dingy-green, light and dark, less lustre, and of coarser texture than diopside. *Fassaite*, (Ca,Mg,Fe, with a little Al), crystals of a rich green color, smooth and lustrous.

Coccolite, granular pyroxene, green, and white. *Asbestus* includes fibrous varieties of both pyroxene and hornblende, but is usually the latter.

II. Dark-colored.

Augite, (Ca,Mg,Fe,Al). G.=3.3–3.5. Greenish-black and black crystals; occurring in eruptive rocks.

Hedenbergite, (Fe and Ca), color black; crystals lamellar-massive. *Jeffersonite*, (Ca,Fe,Zn,Mg), color greenish-black; crystals often very large.

Polylite and *Hudsonite* belong here. These dark-colored varieties are more fusible than the light-colored, and the globule obtained is colored black by the iron oxide.

III. *Diallage* is a thin, foliated variety, often found with serpentine and other rocks. Differs from bronzite and hypersthene in crystalline form, and in being fusible.

Amphibole. Formula as for pyroxene, and blowpipe characteristics the same. H.=5–6; G.=2.9–3.4. Monoclinic. Cleavable at 124½° and 55° 30′, by which it is distinguished from pyroxene. Often in long, slender, flat, rhombic, also six-sided, prisms; also columnar, coarse and fine fibrous, lamellar, and granular; color white to black, passing through various shades of green; lustre vitreous, with cleavage face sometimes pearly.

Varieties:

I. Light-colored. G. 2.9–3.3.

Tremolite and *Grammatite*, (Mg,Ca). Color white to dark-gray; in crystals, columnar, fibrous, compact, granular-massive.

Actinolite, (Mg,Ca,Fe). Light-green varieties; in bright-green crystals, columnar, fibrous, often radiated, and also granular-massive.

Asbestus, slender, flax-like fibres, green, gray, or white. *Amianthus*, white, silky. Ligniform asbestus, mountain leather, and mountain cork, usually white or grayish-white, belong here.

Nephrite is a tough, compact variety, closely related to tremolite. These light-colored varieties contain little or no alumina or iron.

II. Dark-colored. G. = 3–3.4.

Hornblende, (Mg,Ca,Al,Fe), black and greenish-black crystals and massive. *Pargasite*, dark-green, short and stout crystals. *Cummingtonite*, color gray or brown; usually fibrous, and often radiated.

III. *Smaragdite*, a thin, foliated variety of a light-green color, resembling common diallage.

Titanite, $CaTiSiO_5$. Fusibility 3. H. = 5–5.5. Monoclinic; gives the titanium reaction (par. 125); imperfectly soluble in hydrochloric acid.

Guarinite, $CaTiSiO_5$, of similar composition, but dimetric.

Keilhauite, containing 28 per cent. of TiO_2; also alumina and yttria. Fuses, with intumescence, to a black shining glass. Yields with borax an iron-colored glass, which, in the inner flame, becomes blood-red. Reaction of manganese with soda. Decomposed by hydrochloric acid.

Orthoclase, $K_2\overline{Al}Si_6O_{16}$; **Albite,** with potash replaced by soda, $Na_2\overline{Al}Si_6O_{16}$. Hardness 6; fuse without intumescence. Fusibility of orthoclase 5; of albite, 4; the latter colors the flame yellow. Not soluble in acids. With cobalt solution become blue on the edges (par. 44). Orthoclase cleaves in two directions at right angles, 90°; albite at 93° 30′, and show striæ on one surface.

Oligoclase, $(Ca,Na_2,K_2)\overline{Al}Si_5O_{14}$, is more fusible than albite (3.5). It sometimes resembles labradorite, but, unlike it, is not materially acted upon by acids. The cleavage surface shows the striæ in a marked degree; if the mineral is powdered, mixed with ammonium fluoride, and ignited in a platinum dish, then boiled with hydrochloric acid, neutralized with ammonia, and filtered, the lime in the filtrate may be precipitated with ammoninum oxalate. *Tschermakite,* $(Na_2Ca)\overline{Al},Si_5O_{14}$.

Hyalophane, $(Ba,K_2)\overline{Al}Si_4O_{12}$, is very similar to these minerals, but, if fused with potash, treated with hydrochloric acid and water, the solution gives a precipitate of barium sulphate with sulphuric acid.

Zoisite, $H_2Ca_4(\overline{Al}\overline{Fe})_3Si_6O_{26}$, and **Epidote,** $H_2Ca_4(\overline{Al}\overline{F})_3Si_6O_{26}$. Hardness 6.5; fusibility 3–3.5; fuse with intumescence—zoisite to a white or yellowish slag; epidote to a black or dark-brown slag. After fusion they gelatinize with acid. Color of zoisite gray, yellowish-gray, grayish-white; of epidote, green.

Garnet [var. *Grossularite*], $Ca_2\overline{Al}Si_3O_{12}$; [var. *Pyrope*], $(Mg,Ca,Fe,Mn)_3Al_2Si_3O_{12}$; and **Vesuvianite,** Ca (or Mg, Fe, or $H_2,K_4Na_2)\overline{Al}$, or $\overline{Fe}Si_7O_{28}$. Hardness 6.5–7.5; fusibility of lime-garnet and vesuvianite, 3; of pyrope, 4.5. Vesuvianite possesses cleavage; the others not. Pyrope gives, with the fluxes, the chromium reactions, is not acted upon by acids, and is of a blood-red color. The

others green, yellowish-brown, hyacinth-red, and white. The *Edelforsite* and *Sphenoclase* of Von Kobell belong here.

Monzonite resembles grossularite, but does not gelatinize after fusion, and is not decomposed by hydrochloric or sulphuric acid. Color gray-green. See also *Emerald*, *Euclase*, *Iolite*, *Biotite*, and *Muscovite*.

Obsidian, Pitchstone, Pearlstone, and **Pumice,** SiO_2,AlO_3,FeO_3,CaO,MgO,Na_2O,K_2O,H_2O, are amorphous. Fusibility **3.5–4**; fuse, with intumescence, to porcelain-like masses or white vesicular glasses. Lustre of obsidian glassy; of pitchstone, greasy; of pearlstone, pearly. Pumice is characterized by its porosity. Pitchstone usually yields water in the matrass.

CLASS III. Infusible, or fusibility above 5.

Division 1. After ignition, moistened with cobalt solution and again ignited, assume a bright-blue color (*alumina*).

(Some minerals should be first calcined and pulverized.)

With the hard, anhydrous minerals of this division the color is best seen by reducing the substance to a fine powder and moistening this with the cobalt solution. The color appears only after cooling, and by daylight.

Section 1. Give much water in a matrass.

Ralstonite, Al,F, etc., gives off hydrofluoric acid when warmed with sulphuric acid.

Alunite, $K_2Al_3S_4O_{22} + 6$ aq, and **Aluminite,** $AlSO_6 + 9$ aq, with soda on coal give a sulphur reaction, which is not the case with the following minerals. Aluminite is readily soluble in hydrochloric acid; alunite, not visibly affected. By calcination alunite loses 13 per cent. water,

aluminite 47, and a similar mineral, *Felsobanyite*, 37 ($Al_2O_3SO_9 + 10aq$).

Pissophanite, AlO_3,FeO_3SO_3,H_2O, blackens in the flame, to which it gives a greenish tinge, burns and falls to pieces. Aluminite is white and opaque, while the latter is greenish and transparent.

(See also *Kalinite*, *Alunogen*, and *Tschermigite*, which are soluble in water, while the foregoing are not.)

Plumbogummite, see par. 264; **Calamine**, see par. 304.

Gibbsite, H_6AlO_6; **Diaspore**, H_2AlO_4; *Seybertite*, $(Mg_6Ca_6Al_2Fe_2)SiO_2$; and *Pholerite*, $Al_4Si_3O_{12} + 4H_2O$. Gibbsite is easily soluble in potassium hydrate, and loses by ignition 34.5 per cent. water. The others are insoluble in potash. Distinct cleavage in one direction. Seybertite loses 4½ per cent. water by ignition. Color wax-yellow. Diaspore and pholerite lose 15 per cent., and may be distinguished from the other minerals by their hardness—diaspore, **6**; pholerite, **1**. The last often occurs in scales, with a mother-of-pearl lustre.

The following minerals of similar composition are for the most part soluble in caustic potash. If an excess of nitric acid is added to the solution and boiled with ammonium molybdate, a yellow precipitate is formed. In the closed tube give the phosphoric acid reaction (see par. 110).

Wavellite, $Al_3P_4O_{19} + 12aq$, loses by ignition 27 per cent. of water.

Evansite, $Al_3P_2O_{14} + 18aq$, loses by ignition 40 per cent. of water.

Peganite, $Al_2P_2O_{11} + 6aq$, loses by ignition 24 per cent. of water.

Fischerite, $Al_2P_2O_{11} + 8aq$, loses by ignition 29 per cent. of water.

Berlinite, $2\dot{A}lP_2O_8 + aq$, loses by ignition 4 per cent. of water.

Zepharovichite, $\dot{A}lP_2O_8 + 6\,aq$, loses by ignition 27 per cent. of water.

Trolleite, $\dot{A}l_4P_6O_{27} + 3\,aq$, loses by ignition 6 per cent. of water.

Sphærite, $\dot{A}l_5P_4O_{25} + 16\,aq$, loses by ignition 24 per cent. of water.

Redondite, $\dot{A}lO_3, \dot{F}eO_3, P_2O_5, H_2O$, loses by ignition 23 per cent. of water.

Tavistockite, $Ca_3\dot{A}lP_2O_{11} + 3\,aq$, loses by ignition 12 per cent. of water.

Amphithalite, $\dot{A}lO_3, CaO, P_2O_5, H_2O$, loses by ignition 12 per cent. of water.

Cœruleolactite, $\dot{A}l_3P_4O_{19} + 10\,aq$, loses by ignition 21 per cent. of water.

These minerals are of various grayish shades of green, yellow, red, and brown to white, and vitreous or pearly lustre. H.=3–6; G.=2–3.

Allophane, $\dot{A}lSiO_5 + 5\,aq$; *Halloysite*, $AlSi_2O_7 + 4\,aq$; *Samoite*, $\dot{A}l_2Si_2O_{12} + 10\,aq$; *Collyrite*, $\dot{A}l_2SiO_8 + 9\,aq$. Decomposed by hydrochloric acid, with separation of gelatinous silica. Hardness of allophane, 3; gelatinizes completely; often colors the flame green, showing the presence of copper; and loses by ignition 42 per cent. of water. Amorphous. The hardness of samoite is 4; structure laminated, and loses by ignition 30 per cent. The hardness of the others is 1–2. Halloysite loses on ignition 16 per cent. of water; collyrite, 33.5.

Cimolite, $\dot{A}l_2Si_9O_{24} + 6\,aq$; **Kaolinite**, $\dot{A}lSi_2O_7 + 2\,aq$, are very soft and earthy, and but little affected by acids; lose on ignition from 12 to 16 per cent. of water. Nearly related to these minerals are the various varieties of com-

mon *clay*, some varieties of *Lithomarge* (with 14 per cent. of water), and *Schrötterite*, with 35 per cent. of water, *Miloschite* and *Halloysite*, with 24–26 per cent. of water; the clays become plastic with water; the latter three not, but fall to pieces.

Compare also *Lazulite*, *Svanbergite*, *Pyrophyllite*, *Disterrite*, *Wörthite*, *Myelin*, *Agalmatolite*, which yield water in matrass, but only a very little. Compare also *Ripidolite*.

Section 2. Before the blowpipe in a matrass give no water, or but a trace.

Alumian, AlS_2O_9. Before the blowpipe on charcoal gives the sulphur reaction.

Lazulite, $(Mg,Fe)AlP_2O_9 + H_2O$. Gives the reaction of phosphoric acid (par. 110). Heated, loses its blue color and becomes white. Not affected by acids.

Svanbergite, P_2O_5,SO_3,AlO_3,CaO, etc. On charcoal gives the sulphur reaction; color yellow, yellowish-brown.

Willemite, Zn_2SiO_4. With cobalt solution (par. 53) becomes blue, and green in spots. Gelatinizes with hydrochloric acid (see par. 303).

Myelin, Al,SiO_5; *Agalmatolite*, SiO_2,AlK_2O,H_2O; **Pyrophyllite,** $AlSi_3O_9 + H_2O$. Are very soft. Hardness 1–2. Pyrophyllite is foliated like talc; before the blowpipe swells up and spreads out into fan-like shapes, increasing to about 20 times its former bulk. The compact varieties do not exfoliate. The others do not change before the blowpipe. Myelin is partially decomposed by hydrochloric acid; agalmatolite not affected.

Westonite, AlO_3,SiO_2,H_2O. Color brick-red. Behaves like pyrophyllite, but is dull, and not of pearly lustre.

Muscovite, $H_2AlSi_2O_8$. Cleavage eminent in one di-

rection; folia elastic; does not swell perceptibly before the blowpipe; fusible in very thin laminæ; with cobalt solution is blue only in spots; not affected by acids; hardness **2.5**.

Brandisite (variety of **Seybertite**). Cleavable in one direction. H. **4–5**. Before the blowpipe fresh pieces become grayish-white and cloudy, and then, moistened with cobalt solution and ignited, become distinctly blue. Decomposed by concentrated sulphuric acid.

Andalusite, $AlSiO_5$; **Cyanite,** $AlSiO_5$, are but little affected by acids. Cyanite occurs generally in bladed crystals; cleavage very perfect at 106°. H.=**5–7**. Color blue, white, gray, black. Hardness of andalusite **7.5**. Andalusite with salt of phosphorus is decomposed, leaving a skeleton of silica in the bead. It cleaves in two directions at 91½°. H.=**7.5**; G.=**3.5**.

Sillimanite, Wörthite, Monrolite (vars. of **Fibrolite**), $AlSiO_5$, are closely related.

Topaz, $AlSi(O,F_2)_5$; **Rubellite** [Tourmaline], $(Li, Na,K)_6Al_6B_2Si_9O_{45}$. Not affected by acids. Not completely soluble in salt of phosphorus; the glass becomes opalescent on cooling. Topaz on being ignited remains transparent and does not swell. Fused in the open tube with salt of phosphorus, gives the fluorine reaction. Topaz is cleavable in one direction. H.=**8**. Rubellite on being ignited becomes white and swells; fused with acid potassium sulphate and fluorite, gives a green flame (boric acid). Is pyro-electric. No cleavage. H.=**6.5**; G.=**3**.

Corundum [Sapphire], AlO_3; **Chrysoberyl,** $BeAlO_4$. Not affected by acids. When pulverized, slowly but completely soluble in salt of phosphorus; the glass does not opalesce on cooling. Hardness of chrysoberyl

8.5; G.=3.7; of corundum, 9; G.=4. Color of the former usually green; of the latter, blue, red, yellow, brown.

Compare *Spinel.*

(Some varieties of *Leucite* assume a blue color with cobalt solution, but its hardness is not over 6. *Cassiterite*, also, in fine powder, takes a blue color; also green. Gives with cyanide of potassium globules of tin. *Quartz* also takes a pale-blue color with a reddish tinge.)

Division 2. Moistened with cobalt solution and ignited, assume a green color.

It is sufficient to heat to redness. The minerals of this division give a coating of zinc oxide on charcoal, par. 34.

Smithsonite, see par. 302.

Hydrozincite [Zinc Bloom], $Zn_3CO_5 + 2aq$. Dissolves readily in hydrochloric acid with effervescence; the solution gives with ammonia a white precipitate, soluble in an excess of the reagent. Yields water in a matrass.

Willemite, see par. 303; **Calamine,** see par. 304. Gelatinize with hydrochloric acid. Calamine yields water, willemite not. With cobalt solution assume a green color only in spots.

(See *Sphalerite* and *Goslarite*, also *Cassiterite.*)

Division 3. After ignition have an alkaline reaction, and change to reddish-brown the color of moistened turmeric paper.

Brucite, H_2MgO_2; *Hydrodolomite*, $3(Ca,Mg)CO_3 + H_2O$; **Hydromagnesite,** $Mg_4C_3O_{10} + 4aq$. Yield much water in a matrass, unlike the other minerals of this

division. Brucite dissolves in hydrochloric acid without effervescence, hydromagnesite with effervescence. The concentrated hydrochloric acid solution of the hydromagnesite is not precipitated by sulphuric acid, while the latter yields a heavy precipitate. *Predazzite*, $2CaCo_3 + H_2MgO_2$, and *Pencatite*, $CaCo_3 + H_2MgO_2$, are similar in behavior to the hydrodolomite. *Pyrochroite*, $H_2(MnMg)O_2$, is similar in reactions to brucite, but boiled with concentrated phosphoric acid, gives, on addition of nitric acid, a violet-red solution. *Lancasterite* is a mixture of brucite and hydromagnesite. *Nemalite* is a fibrous variety of brucite, of silky lustre.

Calcite, $CaCo_3$; **Aragonite,** $CaCo_3$. Dissolve readily and with effervescence in dilute cold hydrochloric acid; the concentrated (but not the dilute) solution gives a precipitate with sulphuric acid. Aragonite falls to powder before the blowpipe, calcite not. Calcite, H.=3; G.=2.6–2.8; aragonite, H.=3.5–4; G.=2.9–3. (See *Strontianite.*)

Dolomite, $(Ca,Mg)Co_3$; **Magnesite,** $MgCo_3$. Do not, or but slightly, effervesce with cold dilute hydrochloric acid, but dissolve readily on application of heat. The concentrated solution of the former gives a precipitate with sulphuric acid, that of the latter not.

Compare *Siderite*, see par. 254, and *Rhodochrosite*, see par. 274.

Strontianite, $SrCO_3$; **Barytocalcite,** $(Ba,Ca)CO_3$. Dissolve with effervescence in dilute hydrochloric acid; the solution, even if largely diluted with water, gives a precipitate with sulphuric acid. Strontianite colors the flame red, par. 59; barytocalcite, yellowish-green, par. 60.

Compare *Yttrocerite;* also *Talc* and *Muscovite*, which, after ignition, sometimes give an alkaline reaction.

Division 4. Completely soluble, or nearly so, in hydrochloric or nitric acid, without gelatinizing by evaporation or leaving a considerable residue of silica.

Lithiophorite, $MnO,CuO,CoO,Li_2O,BaO,\overset{\Delta}{Al}O_3,MnO_2,H_2O$. Color bluish-black. Colors the flame carmine-red.

Ludwigite, $\overset{\Delta}{Fe}O_3,FeO,MgO,BaO_3$. Color black. Difficultly fusible. With sulphuric acid and alcohol give the green flame of boric acid.

Cervantite, $Sb_2O_3 + Sb_2O_5$. Before the blowpipe, on coal, infusible, but with soda easily reduced to metallic antimony. Color yellowish.

Stibiconite, $SbO_2 + H_2O$; and *Volgerite,* $Sb_2O_5 + 5\,aq$, are similar. They yield water in the matrass, the former 5 per cent., and the latter 15 per cent.

Siderite, see par. 254; **Rhodochrosite,** see par. 274; **Zaratite,** see par. 284. Dissolve in hot hydrochloric acid with effervescence.

Mesitite, $Mg_2FeC_3O_9$. Blackens and becomes magnetic before the blowpipe. Slightly acted upon in the cold by acids; but, if powdered, dissolves readily with effervescence in hot hydrochloric acid. Color yellowish-white to brown. Streak, nearly white.

Ankerite, $(Ca,Fe,Mg)CO_3$, is similar to the last. If dissolved in aqua regia, the iron precipitated by ammonia, a heavy precipitate will be formed on addition of ammonium oxalate.

Hydrotalcite, $\overset{\Delta}{Al}O_3,MgO,H_2O,CO_2$. Yields water in matrass. Does not become magnetic in the reduction flame. In powder, effervesces with hydrochloric acid and dissolves completely. If the solution is neutralized

with sodium carbonate and filtered, ammonium oxalate gives no precipitate in the filtrate, but a precipitate is formed by hydro-disodium phosphate and ammonia.

Parisite, $3(Ce,La,Di)CO_3+(Ca,Ce)F_2$, is slowly soluble in hydrochloric acid with effervescence. The solution, not too acid, gives a white precipitate with oxalic acid, which becomes brick-red by ignition (*cerium oxide*).

Limonite, see par. 248; **Göthite,** see par. 249.

Turgite, $H_2Fe_2O_7$, forms a brownish-red powder, and loses by ignition 5.7 per cent. of water (see par. 250).

(See also *Hematite*, which in some varieties is without metallic lustre; readily distinguished by its red streak.)

Sphalerite, see par. 300; *Greenockite*, CdS. Dissolve in hydrochloric acid with evolution of sulphuretted hydrogen. Give the sulphur reaction, par. 121. Greenockite gives on charcoal a coating of cadmium oxide, par. 35, the others of zinc oxide, par. 34. *Marmatite*, FeS + 3 ZnS, gives, after calcination with the fluxes, the reactions of iron.

Wad, see par. 273; **Zincite,** see par. 301.

Asbolite (var. of *Wad*), see par. 273. Some varieties are fusible.

Uraninite, U_3O_8; *Zippeite*, $U_3S_2O_{15}+12H_2O$. Give with the fluxes the reactions of uranium sesquioxide (Table II.). Give with nitric acid a yellow solution, in which ammonia produces a sulphur-yellow precipitate. Uraninite is black; zippeite, yellow. G. of uraninite, **6.5.**

Turquois, $Al_2P_2O_{11}+5$ aq with Cu. Color sky-blue to green. Gives the copper reaction, par. 91. Mostly soluble in caustic potash, leaving a residue of brownish color containing copper. The solution in nitric acid

gives a yellow precipitate with ammonium molybdate. Yields much water in a matrass. G.=**2.6–2.8.**

Apatite, $3\,CaP_2O_8 + Ca(Cl,F)_2$. Gives the phosphoric acid reaction, par. 110. Fusibility **5**. Soluble in nitric acid. If the solution is not too acid, a precipitate of lead phosphate is formed with the acetate, and of calcium oxalate with ammonium oxalate. G.=**3.2.**

Monazite, $5(Ca,La,Di)_3P_2O_8 + Th_2P_2O_9$. Infusible. Gives the phosphoric acid reaction, par. 110. Soluble in hydrochloric acid. Minute tabular crystals of reddish-brown color. G.=**5.2.**

Childrenite, $(FeMn)_8Al_2P_6O_{29} + 15$ aq. Gives the phosphoric acid reaction, par. 110. With the fluxes gives the reaction of iron and manganese. Soluble with difficulty in hydrochloric acid. After ignition is magnetic. Moistened with sulphuric acid, colors the flame greenish. Yields much water. Sp. gr. **3.2.**

Polycrase, $YO,TiO_2,Cb_2O_5,FeO,UO_2H_2O$, etc. Decrepitates, but infusible. Color black. On fusing the pulverized mineral with caustic potash, dissolving the fused mass in water, neutralizing the filtrate with hydrochloric acid, a precipitate is formed, which, boiled with an excess of concentrated hydrochloric acid and tin-foil, gives a cloudy blue solution, which filters clear and blue after the addition of a little water. This solution colors turmeric paper orange-yellow. G.=**5.**

Fluocerite, Ce_3F_8, and *Bastnäsite,* $Ce_2F_6 + Ce_2O_3 + 4$aq, give the reactions of fluorine, par. 92, and of cerium sesquioxide (Table II. 5). Bastnäsite gives off carbon dioxide when treated with acids. Their color is yellow. G.=**4.7–4.9.** *Yttrocerite,* $(Ca,Ce,Y)F_2$, behaves similarly, but has an imperfect cleavage in two directions. G.=**3.5.**

Division 5. With hydrochloric acid gelatinize, or decompose with separation of silica.

Section 1. Before the blowpipe give water in a matrass.

Dioptase, H_2CuSiO_4 emerald green; **Chrysocolla**, see par. 234, blue to green, H.= **2–4**; *Cyanochalcite*, CuO,P_2O_5,SiO_2,H_2O, azure-blue, H.= **4.5**, lustre dull. Behave alike before the blowpipe; the first gelatinizes with acids, the latter not.

Uranotile, $Ca_2U_6Si_5O_{30} + 15$ aq. Color lemon-yellow, lustre vitreous. Acicular crystals.

Xonaltite, $4CaSiO_3 + H_2O$. Massive; very hard; white to gray; yields water; infusible (?); decomposed by hydrochloric acid, in which solution of ammonium oxalate gives a heavy precipitate, but ammonia none.

Thorite, $Th,SiO_4 + H_2O$; *Cerite*, $(Ce,La,Di)_2SiO_4 + H_2O$. Gelatinize with hydrochloric acid. The solution of cerite, not too acid, gives, with ammonium oxalate, a white precipitate, which becomes brick-red if ignited on platinum (cerium oxide). Color of thorite is black; streak dark-brown; hardness **4.5–5**; of cerite, brown to red, passing into gray; streak white; hardness **5.5**. Their sp. gr. is **4.9–5.4**.

Chloropal, $Fe_2Si_3O_9 + 5$ aq; *Wolchonskoite*, $MgO,Al_2O_3,Cr_2O_3,Fe_2O_3,SiO_2,H_2O$; and *Genthite*, $H_4(Ni,Mg)_4Si_3O_{12}$. Amorphous, with resinous lustre (see par. 285). Wolchonskoite is dark sea-green, and gives with borax an emerald-green bead, which continues when cold. The others are yellowish-green. Chloropal gives a green bead, which fades on cooling, and genthite a violet bead in oxidizing flame, becoming gray in reducing flame. If the mineral is powdered and moistened with potassa, the chlo-

ropal becomes black without boiling; genthite turns brown after boiling until concentrated; and wolchonskoite is not changed. The hydrochloric acid solution of genthite with ammonium in excess becomes azure-blue. Genthite gives off water in the closed tube and blackens.

Compare *Gillingite*, Div. 5, p. 250, and *Xylotile*, Div. 5, Sect. 3. Become magnetic by ignition; readily decomposed by hydrochloric acid. Gillingite is black; amorphous; xylotile is light- or dark-brown; of fibrous, woody structure.

Sepiolite, $Mg_2Si_3O_8 + 2aq$, gelatinizes with hydrochloric acid; very light; G.=**1.5**; absorbs water with great avidity; gives the magnesia reaction with cobalt solution (par. 53); before the blowpipe turns white and shrinks; forms a jelly-like mass with hydrochloric acid.

Bastite or *Schiller-spar* [impure Serpentine]; *Chrysotile*, $Mg_3Si_2O_7 + 2aq$, possess a metallic, pearly lustre; the former is massive, cleavable; the latter fibrous. By ignition schiller-spar becomes brown; chrysotile, white. Both are decomposed by hydrochloric acid, or more readily by sulphuric acid, without gelatinizing. *Metaxite* is greenish-white, similar to chrysotile.

Cerolite, $H_2Mg_2Si_2O_7 + H_2O$. Amorphous; H.=**2–3**; G.=**2.3**. Color greenish, yellowish, reddish. Before the blowpipe blackens, but does not fuse. Ignited with cobalt solution, a pale flesh-red color. By ignition loses 30 per cent.

Serpentine, $Mg_3Si_2O_7 + 2aq$; often with Fe, Ni, and Cr. Decomposed by concentrated hydrochloric acid without gelatinizing. Usually massive and compact; hardness **3–4**; loss by ignition, 12 to 13 per cent. Of similar composition, and showing a similar behavior, are the following minerals, which, however, possess crystalline structure

and cleavage: *Picrophyll*, fibrous; greenish-gray; hardness 2.5; loss by ignition, 10½ per cent. *Picrosmine*, greenish-white, dark-green, gray; hardness 2.7; loss by ignition, 9 per cent. *Marmolite*, greenish and bluish-white; hardness 2.5–3; loss by ignition, 15.7 per cent. *Antigorite*, hardness 2–5; loses by ignition, 4 to 6 per cent. *Penninite*, $Mg_2Al_2Si_3O_{14} + 4aq$. H. = 2.5; lustre pearly; color green, gray, red; crystals often tabular and in regular groups; gives little water and exfoliates.

(See also *Chlorite* and *Ripidolite*, which are with difficulty decomposed by concentrated hydrochloric acid.)

Monradite, $4(Mg,Fe)SiO_3 + H_2O$; *Neolite*, MgO,AlO_3,SiO_2,H_2O. Decomposable by concentrated hydrochloric acid without gelatinizing; loss by ignition, 4 to 6 per cent. Monradite, hardness 6; neolite, in silky fibres, or massive; hardness 1.

(See also some varieties of *Seybertite*, $Mg_6Ca_6Al_2Fe_2SiO_8$. Hardness 4–5; lustre pearly, submetallic; color yellow, reddish-brown, copper-red.)

Section 2. Before the blowpipe in a matrass give no water, or but a trace.

Gadolinite, $SiO_5(Y,Fe,Ce,Be)_3$; *Gehlinite*, $Ca_3(AlFe)Si_2O_{10}$, gelatinize with hydrochloric acid. Gadolinite swells before the blowpipe into cauliflower-like masses, and sometimes exhibits a vivid glow; thin splinters fusible on the edges; color black to blackish-green; hardness 6.5–7; G. = 4–4.3. Gehlinite is also fusible in very thin splinters; color gray to grayish-white; hardness 5.5–6; G. = 3.

Chrysolite, $(Mg,Fe)_2SiO_4$; H. = 7; **Chondrodite,** $Mg_8Si_3O_{14}$, with part of the oxygen replaced by fluorine. H. = 6.5; gelatinize with hydrochloric acid; color of the

former, green; of the latter, mostly white, yellow, or brown. Chondrodite gives the fluorine reaction (par. 93). *Monticellite*, $(Ca,Mg)_2SiO_4$, is isomorphous with chrysolite. H.=5–5.5; color yellowish, greenish-gray, and white.

Compare *Roepperite*, p. 249.

Forsterite, Mg_2SiO_4. Cleavage distinct in one direction; color white, grayish, yellow, wax-yellow; before the blowpipe unaltered and infusible; decomposed by HCl, with separation of gelatinous silica. Var. *Baltonite* gives traces of moisture in matrass and becomes colorless. (See also *Seybertite*.)

Leucite, $K_2Al_2Si_4O_{12}$, decomposed by hydrochloric acid, the silica separating as a fine powder; some varieties become blue with cobalt solution; occurs usually in trapezohedrons; color grayish or white. H.=5.5; G. =2.5.

Division 6. Not belonging to either of the preceding divisions.

The remaining minerals, which cannot be classed under any of the preceding divisions, may be divided, according to their hardness, in two sections.

Section 1. Hardness below 7.

Biotite [Hexagonal Mica], $K_2(FeMg)_7AlSi_7O_{28}$; **Muscovite** [Oblique Mica], $K_2AlSi_2O_8$; **Talc,** $H_2Mg_3Si_4O_{12}$, give little or no water in a matrass. Talc loses at most 5 per cent. Cleavage eminent in one direction. Hardness of biotite, 2.5–3; of muscovite, 2–2.5; of talc, 1–1.5. Talc has a greasy feel, the others not. Biotite is decomposed by concentrated sulphuric acid, the others not. Biotite is optically uniaxial, sometimes biaxial, but the

angle of divergence does not exceed 5°, and seldom 1°. Turned in the stauroscope, the black cross is not changed, while with the others it is changed with various colors. The optic axial-angle of muscovite is 44°–78°, of margarodite the same, and of phlogopite 3°–20°, seldom less than 5°. The laminæ of biotite and muscovite are elastic, of talc not. Soapstone, or *Steatite*, is a massive, usually compact, variety of talc; very greasy to the feel, or like soap. (See also *Pyrophyllite*.) **Margarodite**, $K_2Al,Si_2O_8 + H_2O$, and **Phlogopite**, K_2Mg_6Al,Si_5O_{20}, are decomposed by sulphuric acid. **Margarite**, $Ca,Al_2Si_2O_{11} + H_2O$, with pearly lustre, and *Œllacherite* $K_2(Ba,Mg)Al_2Si_4O_{16}$, with 5½ per cent. baryta, are nearly related to the muscovite.

Prochlorite, $H_{22}(FeMg)_{10}Al_3Si_6O_{42}$; *Delessite*, $Mg,Fe\,AlO_3FeO_3SiO_2,H_2O$; **Ripidolite**, $Mg_5Al,Si_3O_{14} + 4aq.$ Lose by ignition 12 per cent. of water. Cleavage eminent in one direction; laminæ not elastic (both often massive-granular). Hardness of prochlorite, **2**; of ripidolite, **2–2.5**. Delessite has a short fibrous structure. H. = **1–2.5**. Is easily decomposed by concentrated hydrochloric acid, the others only with continued boiling, more readily by sulphuric acid. Ripidolite fuses with difficulty (**5.5**) to a grayish-yellow enamel; prochlorite becomes black and slightly magnetic. Ripidolite gives, with borax, a clear chromium-green glass, and prochlorite a glass colored by iron, which loses color on cooling. Ripidolite is monoclinic; prochlorite, hexagonal.

Leuchtenbergite, H. = **2.5**. Colorless, white, yellowish-white. Before the blowpipe exfoliates and fuses with difficulty on the thin edges, becoming white and opaque. **Penninite**, $Mg_5AlSi_3O_{14} + 4aq.$ H. = **2.5–3** often on edges. Color green, red, and white. With fluxes, all the vari-

eties give the reaction for iron, and many for chromium. Completely decomposed by sulphuric acid. **Chloritoid,** $(Fe,Mg)(\cancel{Al}Fe)SiO_6 + H_2O$, is not perceptibly acted upon by hydrochloric acid, but completely decomposed by sulphuric acid. H.=**5–6.** Loss by ignition, 7½ per cent.

Cerolite. (Compare Div. 5, p. 282.) Amorphous. Yellowish-white. Greasy feel. H.=**2–3.** Loss by ignition, 30 per cent. Mostly decomposed by hydrochloric acid. Does not adhere to the tongue.

Beauxite, $(\cancel{Al}Fe)O_3 + 2$ aq. Amorphous. Often oölitic, grayish, reddish-brown, and red. H.=**3**; G.=**2.5.** Loss by ignition, 20 per cent. Only slightly attacked by hydrochloric acid, but completely dissolved by concentrated phosphoric acid.

Compare *Argillite.*

Wolchonskoite. (See Div. 5, p. 281.) Amorphous. Color dark-green. Boiled with phosphoric acid, it gives an emerald-green solution, which, if diluted with water, retains its color, but gelatinous silica separates out. *Chromite* also gives the chromium reaction, but its color is black, and streak yellowish-brown.

Warwickite, $2\,MgTiO_3 + Mg_4B_6O_{13}$. Its powder is decomposed by sulphuric acid; evaporated to dryness and moistened with alcohol, it gives the green flame. If this mass is boiled with hydrochloric acid and tinfoil, and concentrated, the solution is violet; or, diluted with water, rose-red.

Enstatite, $MgSiO_3$; **Anthophyllite,** $(Mg,Fe)SiO_3$. Cleavage of enstatite very perfect in one direction; anthophyllite cleaves in two directions, under 124° 30′. The former is of clove-brown or pinchbeck-brown color, with a pearly-metallic lustre; the lustre of antho-

phyllite is much less perfect. Hardness 5–5.5. **Hypersthene**, $(Mg,Fe)SiO_3$, is closely related, and cleaves at 86½°. H. = 5.5. On charcoal, before the blowpipe, gives a magnetic mass.

Tungstite, WO_3. Boiled with phosphoric acid, it gives a bluish solution, which, shaken while warm with iron filings and a little water, becomes dark-blue. Occurs in soft, earthy, yellow masses.

Scheelite, $CaWO_4$. Fusibility 5; hardness 4.5–5. The pulverized mineral, on being boiled with nitric acid, leaves a lemon-yellow residue of tungstic acid. Gives the reactions of tungstic acid (Table II.).

Cassiterite, see par. 299.

Octahedrite, **Rutile** (both dimetric, with adamantine lustre), and **Brookite**, (trimetric), TiO_2. Give the reactions of titanic acid (Table II.). On fusing the pulverized minerals with caustic potash, dissolving the fused mass in hydrochloric acid, and boiling the solution with metallic tin, it assumes a violet color, which turns to red on addition of water. Color of octahedrite, various shades of brown, passing into indigo-blue; of rutile, mostly brownish-red or red, sometimes yellowish or black; of brookite, hair-brown, yellowish, or reddish (variety *Arkansite* is iron-black). Hardness of octahedrite, 5.5–6; of rutile, 6–6.5; of brookite, 5.5–6.

Euxenite, $(Y,Fe,U)_3Ti_2Cb_2O_{12}H_2O$, and *Æschynite*, $(Ce,La,Di,Fe,Y)_3Cb_2(Ti,Th)_3O_{14}$; *Pyrochlore*, $Cb_2O_5TiO_2$, ThO_2CeO,CaO,FeO,Na_2O,F. Treated like the preceding with potash, etc., the solution, on reaching a certain degree of concentration, assumes a fine blue color, on addition of water, which changes in the air to olive-green, and gradually disappears. Æschynite swells before the blowpipe, and turns yellow or brownish. The color is

black; the powder light-brown. Euxenite unaltered before the blowpipe. Color brownish-black. Powder reddish-brown. They have a metallic, greasy lustre. Pyrochlore is distinguished by its octahedral form. Color brownish-red, and powder light-yellow.

Opal, $SiO_2 + aq$. Amorphous. Before the blowpipe yields water and becomes opaque; fuses with soda to a clear bead, with effervescence. Infusible. Boiled with potassium hydrate, it dissolves completely or to a great extent; the solution gives a gelatinous precipitate with ammonium chloride. Hardness **6–6.5.** G. = **2–2.3.**

Xenotime, $(Y,Ce)_3P_2O_8$. Color various shades of brown or flesh-red. Hardness **4–5.** G. = **4.4.** Gives the phosphoric acid reaction, par. 94. Infusible. With salt of phosphorus dissolves with great difficulty to a colorless glass.

(See also *Childrenite* and *Orthoclase.*)

Section 2. Hardness 7, or above.

(See *Cassiterite*, *Rutile*, and *Opal* of the preceding section, whose hardness sometimes approaches **7.**)

Quartz, SiO_2. The several varieties of quartz, **Rock-crystal, Amethyst, Hornstone, Flint, Chalcedony,** etc., are infusible and unalterable before the blowpipe, and fuse with soda to a transparent bead, with effervescence. Alone in the strongest heat are unaltered and infusible. In a fine powder, fused with potash, the mass is more or less soluble in water. In this solution, ammonium chloride in excess gives a heavy white precipitate (*hydrated silica*). H. = **7,** and gives sparks with steel; G. = **2.6.** *Tridymite*, SiO_2, crystallizes in microscopic hexagonal plates. G. = **2.2–2.3.**

Iolite, $(Mg,Fe)_2Al_2Si_5O_{18}$; **Staurolite,** $H_2(Mg,Fe)_3Al_6$

Si_6O_{34}, do not fuse to a transparent glass with soda. Fusibility of iolite, **5–5.5**; color blue, grayish; G.=**2.6.** Staurolite is infusible; color brownish-red, brown; crystals often cruciform; G.=**3.6.**

Beryl, $Be_3AlSi_6O_{18}$; *Euclase,* $H_2Be_2AlSi_2O_{10}$; *Phenacite,* Be_2SiO_4; **Zircon,** $ZrSiO_4$. Hardness **7.5.** Beryl and euclase turn milk-white with strong heat, and become rounded on the edges; beryl crystallizes in hexagonal prisms and possesses quite distinct basal cleavage; color usually pale-green or emerald-green. Euclase crystallizes in clinorhombic prisms, and possesses distinct cleavage in two directions at right angles to each other; color pale mountain-green, passing into blue and white. Phenacite and zircon do not change before the blowpipe, excepting that zircon becomes colorless; color red, yellow, or colorless; zircon sometimes brown or gray. Zircon, powdered, fused with potash, and boiled with hydrochloric acid, the diluted solution colors turmeric paper orange-red. If the acid solution is concentrated to crystallization, boiled with a saturated solution of potassium sulphate, a white precipitate is formed (*zirconia*). Phenacite is a little harder (**8**) than zircon. G. of zircon, **4.4**; of the others, **2.7–3.**

Topaz, $AlSi(O,F_2)_5$. H.=**8**; G.=**3.5.** Orthorhombic. Before the blowpipe infusible. Some varieties take a wine-yellow or pink tinge when heated. Fused in an open tube with salt of phosphorus, gives the fluorine reaction. With cobalt solution the pulverized mineral gives a fine blue on heating. Very slightly attacked by sulphuric acid.

Ouvarovite [Lime-chrome Garnet], $Ca_3CrSi_3O_{12}$. Emerald-green; infusible, but by ignition becomes blackish-green, and on cooling again, emerald-green. H.=**7.5–8**; G.=**3.5.** Gives with fluxes the chromium reactions (Table II.).

Spinel, $(Mg,Fe)(AlFe)O_4$ (*Pleonaste*); **Gahnite,** $(Zn, Mg)(AlFe)O_4$. Hardness **7.5–8**; occur almost exclusively in octahedral crystals. Spinel and pleonaste, when pulverized, are soluble in salt of phosphorus; color of spinel, red, blue, brownish; of pleonaste, black. Gahnite is almost insoluble in salt of phosphorus and borax; color dark-green or black. *Kreittonite* is a black gahnite containing zinc and iron, slightly magnetic before ignition; so also *Dysluite*. The specific gravity of the last three = **4.3–4.6**; and of the other spinels = **3.6.**

Diamond, C. Characterized by its hardness, which surpasses that of corundum. H. = **10**; G. = **3.5–3.6.**

Mineral Coal, see pars. 306–308. *Albertite*, color jet-black; slightly soluble in camphene. *Grahamite*, color pitchy-black; mostly soluble in camphene. *Asphaltum*, see par. 309.

Simple Hydrocarbons. *Marsh Gas*, CH_4, **Petroleum,** mineral oils of density from 0.60–0.85, *Hatchetite*, *Ozocerite*, *Urpethite*, *Zietrisikite*, and *Pyropissite* belong here. *Elaterite*, see par. 311. *Fichtelite* and *Hartite* are of the camphene series; also *Dinite* and *Ixolyte*. *Naphthalin* and *Idrialite* belong to the benzole series, and probably *Aragotite*.

Oxygenated Hydrocarbons. *Amber* (see par. 310), *Copalite*, *Ambrite*, *Scleretinite*, *Euosmite*, etc. *Geocerite*, *Geomyricite*, are wax-like. Of those not resinous are—*Guyaquillite*, *Torbanite*, *Ionite*, *Wollingite*, etc. In *Tasmanite* and *Dysodile* part of the oxygen is replaced by sulphur.

Acid Oxygenated Hydrocarbons include—*Butyrellite* (*Bog-butter*), *Succinellite*, *Dopplerite*, etc.

The oxidized minerals, arranged according to their fusibility and behavior before the blow-pipe on charcoal with sodium carbonate.

(From *Plattner's Blow-pipe Analysis.*)

a. Minerals fusible to a bead.

a. With soda yield a fluid bead:

Acmite,
Allanite,*
Axinite,*
Boracite,*
Borax,*
Botryolite,*
Crocidolite,
Cronstedtite,
Datolite,*
Elaeolite,*
Eudialyte,
Garnet,
Helvite,
Hydroboracite,*
Ilvaite,
Labradorite,
Lapis-Lazuli,
Mica, from primitive limestone,
Oligoclase,
Pyrasmolite,
Sassolite,*
Scapolite,*
Sodalite (Greenland),
Spodumene,
Talc, black,
The Zeolites.*

b. With a little soda a bead, with more a slaggy mass:

Amblygonite,
Fluorite,
Garnet, manganiferous,
Manganese, black silicate (hydrous tephroite?),
Okenite,
Orthite,*
Pectolite,
Pyrorthite,
Rhodonite,*
Sodalite,
Sordawalite,
Vesuvianite.*

c. With soda only a slag:

Amphodelite,
Autunite,
Brevicite,
Fahlunite,
Haüynite,
Heterosite,
Iron, phosphates of sesquioxide,
Pharmacolite,
Pharmacosiderite,
Polyhalite,
Pyrargillite,
Pyrope,
Saponite,
Scorodite,
Tourmaline, potash, (black),
Triphylite,
Wolframite.

d. Sink with soda into the charcoal:

Celestite,
Witherite.

* Denotes that the mineral fuses with intumescence, effervescence, etc.

e. Fuse with soda at first more or less perfectly to a clear mass, but are decomposed by a sufficient quantity of soda, and leave behind an infusible crust, while the soda sinks into the coal:

Anhydrite,	Gay-Lussite,	Gypsum,
Cryolite,	Glauberite,	Polyhalite.

f. Yield with soda reguline metal: Minerals consisting of reducible metallic oxides and their reducible salts.

b. Minerals which fuse only on the edges.

a. With soda yield a fluid bead:

Albite,	Nephelite,	Steatite,
Anorthite,	Orthoclase,	Titanite,*
Emerald (beryl),	Petalite,	Turquois.
Euclase,*	Sodalite (Vesuvius),	

b. With little soda a fluid bead; more, a slaggy mass:

Enstatite, Epidote,* Hypersthene, Wollastonite, Zoisite.*

c. Yield with soda only a slag:

Carpholite,	Pimelite,	Scheelite,
Dichroite (iolite) blue,	Pinite,	Serpentine,
Lazulite,*	Plumbogummite,*	Tourmaline,* soda,
Mica,* from granite,	Pyrochlore,	(green).

d. With soda sinks into the coal:

Barite.

e. Fuse or only swell up with soda, but are decomposed by a sufficient amount, leaving an infusible crust, while the soda sinks into the coal:

Apatite (swells up), Barite (calciferous), fuses.

* Denotes that the mineral fuses with intumescence, effervescence, etc.

c. Infusible Minerals.

a. Give with soda a fluid bead:

Agalmatolite,
Dioptase,
Fire-clay,
Hisingerite,
Leucite,
Pyrophyllite,*
Quartz,
Rutile,
Sideroschisolite,
Wolchonskite.

b. With little soda, a bead; with more, a slaggy mass.

Cerite,
Chrysolite,
Gadolinite,*
Phenacite,
Picrosomine,
Talc,
Tourmaline* (lithia).

c. Yield, with soda, only a slag:

Aeschynite,*
Allophane,
Aluminite,
Alunite,
Alunogen,*
Andalusite,
Brucite,
Calamine (a zinc coat),
Cassiterite, with much soda metallic tin,
Chloritoid,
Chromite,
Chrome Ochre,
Chrysoberyl,
Cyanite,
Diaspore,
Fluocerite,
Gahnite (a zinc coat),
Gehlenite,
Gibbsite,
Iron, sesquioxide and its sulphates,
Manganese, oxides,
Oerstedite,
Ouvarovite,
Polymignite,
Spinel,
Staurolite,
Tantalite,
Thorite,
Titanic Iron,
Topaz,
Wörthite,
Xenotime,
Yttrocerite,
Yttrotantalite,
Zircon.

d. Fuse or only swell up with soda, but are decomposed by a sufficient amount, and the soda sinks into the coal, leaving an infusible crust:

Alum (kalinite),
Aragonite,
Barytocalcite,
Calcite,
Dolomite,
Epsomite,
Magnesite,
Wavellite.*

e. Sinks with the soda into the coal:

Strontianite.*

* Denotes that the mineral fuses with intumescence, effervescence, etc.

USE OF CITRIC ACID IN EXAMINING MINERALS.

By Prof. H. CARRINGTON BOLTON, Ph. D.

Annals of the New York Academy of Sciences, Vol. II., No. 1.

The organic acids in common use, especially oxalic, tartaric, and citric acids, possess a power of decomposing minerals little short of that of hydrochloric acid, and in some cases may advantageously replace the mineral acid. Citric acid is the strongest in its action, and in concentrated solutions, with the addition of either sodium nitrate or of potassium iodide, decomposes many minerals with characteristic reactions.

The solution of citric acid employed is saturated in the cold, and the minerals are very carefully pulverized. Only a limited number of reactions have been studied.

This method of examining minerals as to their solubility is particularly useful in *field-work*, owing to the easy portability of the solid organic acid. The solid acid may be carried in a pasteboard box and dissolved in water obtained in the field. When heat is not required, simple tests may be made in a leather cup, indispensable to the travelling mineralogist.

Carbonates.

All carbonates (in fine powder) dissolve with effervescence in a strong solution of citric acid. Magnesite and siderite require to be heated.

Special reactions. Calcium carbonates dissolve in a strong solution of oxalic acid, yielding a fine white precipitate.

Siderite dissolves in the same on heating, yielding a light-yellow granular precipitate of ferrous oxalate.

Witherite yields handsome feathery crystals of $Ba\bar{O}$.

Cerussite and oxalic acid yields a heavy white precipitate.

Sulphides.

Stibnite, galenite, sphalerite, pyrrhotite, and alabandite (in fine powder) are decomposed by a strong solution of citric acid in the cold, yielding H_2S more or less freely.

Bornite, bournonite, kermesite, and jamesonite act similarly on heating.

Argentite, pyrite, chalcocite, marcasite, niccolite, smaltite, chalcopyrite, ullmannite, arsenopyrite, tetrahedrite, (uraninite), millerite, linnæite, cobaltite, pyrargyrite, berthierite, tennantite, bismuthinite, stephanite, hessite, and hübnerite, are decomposed by heating with a solution of citric acid, to which solid KNO_3 (or $NaNO_3$) has been added.

Cinnabar, realgar, and orpiment resist this mixture, but are decomposed by heating with a solution of citric acid and KI (added in solid form).

Molybdenite and proustite resist both these mixtures.

Special reactions. Cinnabar dissolves quickly in a cold solution of oxalic acid, to which solid KI is added; if the KI is not in excess, scarlet crystals of HgI_2 form abundantly.

Galenite dissolves in a mixture of $\bar{C}$ and KI, yielding lustrous yellow flaky crystals of PbI_2.

Distinguishing characteristics. Pyrite, chalcopyrite, and chalcocite are *not* decomposed by citric acid alone, while bornite and pyrrhotite are attacked.

Galenite may be detected in argentite, since the former is attacked by cold $\bar{C}$, yielding H_2S, and the latter is not attacked on boiling.

Pyrargyrite is decomposed by heating with $\bar{C} + KNO_3$, or with $\bar{C} + KI$, while proustite is not attacked.

Sundry minerals.

The following minerals dissolve in a strong cold solution of citric acid without evolution of gases: Brucite,

anglesite, pyromorphite (feebly attacked), vivianite, atacamite, clausthalite, leucopyrite, libethenite, olivenite, brochantite, cryptomorphite, ulexite, mimetite, triplite, pharmacosiderite, pseudomalachite, autunite, wavellite, prochlorite, laumontite, herschelite; these last three with separation of silica.

The following minerals are attacked more or less strongly by a boiling concentrated solution of citric acid:

Zincite, gypsum, apatite, cuprite, limonite, goethite, menaccanite, washingtonite, actinolite, allanite (?), nephilite, leucite, staurolite, vesuvianite, wolframite (?), wulfenite (strongly attacked). Also pyrolusite, wad, hausmannite, manganite, psilomelane; these yielding CO_2 by decomposition of the organic acid.

The manganese oxides are very readily dissolved by oxalic acid.

Silicates.

Prochlorite, laumontite, and herschelite are decomposed by a strong cold solution of citric acid. Willemite, datolite, pectolite, calamine, natrolite are decomposed on heating, with formation of gelatinous SiO_2.

Wollastonite, chrysolite, chondrodite, prehnite, chrysocolla, apophyllite, rhodonite, analcite, chabazite, stilbite, serpentine, chrysotile, retinalite, deweylite, heulandite, are decomposed with a boiling solution of $\bar{C}$, and yield SiO_2.

Magnetite, hematite, and franklinite, also braunite, are somewhat attacked by heating with a mixture of $\bar{C} + KI$.

When the minerals are exposed to the prolonged influence of the acids (10 to 30 days), very different results are obtained; but these are of little value in determining species.

TABLES SHOWING THE BEHAVIOR OF CERTAIN MINERALS WITH CITRIC ACID ALONE AND WITH REAGENTS.

By Prof. H. Carrington Bolton, Ph. D.

I.

Decomposed (in fine powder) by a saturated solution of Citric Acid.

1. IN THE COLD.

A. *Without evolution of Gas.*	B. *With liberation of CO_2.*	C. *With liberation of H_2S.*	D. *With separation of SiO_2.*
Clausthalite,	Calcite,!	Stibnite,	Wollastonite,
Leucopyrite,	Dolomite,*	Galenite,	Rhodonite,!
Atacamite,	Gurhofite,!	Alabandite,!	Chrysolite,
Brucite,	Ankerite,*	Sphalerite,	Willemite,! ‡
Gummite,	Rhodochrosite,*	Pyrrhotite.	Nephelite,
Pyromorphite,*	Smithsonite,*		Lapis-lazuli,
Mimetite,	Aragonite,!		Chondrodite,
Triphylite,	Witherite,!		Pectolite,! ‡
Triplite,	Strontianite,!		Laumontite,! ‡
Vivianite,!	Barytocalcite,!		Chrysocolla,!
Libethenite,!	Cerussite,!		Calamine,! ‡
Olivenite,!	Malachite,!		Apophylite,
Pseudomalachite,	Azurite.*		Thomsonite,!
Wavellite,			Natrolite,! ‡
Pharmacosiderite,!			Mesolite,!
Torbernite,			Analcite,
Autunite,			Chabazite,
Ulexite,!			Herschelite, ‡
Cryptomorphite,!			Stilbite,
Anglesite,			Deweylite,
Brochantite.!			Prochlorite.

! Completely decomposed or dissolved. * Feebly attacked.
‡ Gelatinizes.

2. ON BOILING.

E. *Without evolution of Gas.*	F. *With liberation of CO_2.*	G. *With liberation of H_2S.*	H. *With separation of SiO_2.*
Cuprite,!	Hausmannite,†	Bornite,	Tephroite,‡
Zincite,	Pyrolusite,!†	Jamesonite,*	Ilvaite,
Melaconite,	Manganite,†	Bournonite,*	Phlogopite,*
Goethite,*	Psilomelane,†	Boulangerite,	Datolite,!‡
Limonite,*	Wad,!†	Kermesite,	Prehnite,*
Allanite (?),	Magnesite,!		Heulandite,
Apatite.*	Siderite,!		Serpentine,
Wolframite,*			Chrysotile,
Wulfenite,			Retinalite,
Crocoite,			Bastite,
Gypsum,*			Genthite,
			Gieseckite,*
			Jefferisite,
			Masonite,*
and those in A.	*and those in B.*	*and those in C.*	*and those in D.*

II.

DECOMPOSED BY BOILING WITH A SOLUTION OF CITRIC ACID ON THE ADDITION OF—

I. *Sodium Nitrate.*		K. *Potassium Iodide.*	
Silver,	Smaltite,!	Realgar,*	Pargasite,*
Mercury,	Cobaltite,!	Orpiment,*	Olivine,
Copper,	Ullmannite,!	Cinnabar,!	Almandite,
Arsenic,	Marcasite,!	Hematite,*	Pyrope,
Antimony,	Arsenopyrite,!	Menaccanite,*	Colophonite,
Bismuth,	Nagyagite,	Washingtonite,*	Epidote,
Sulphur,*	Covellite,!	Magnetite,*	
Bismuthinite,	Berthierite,!	Franklinite,	*and most of*
Domeykite,!	Pyrargyrite,	Braunite,	*those in*
Argentite,	Tetrahedrite,!	Enstatite,	*A, B, C, D,*
Hessite,	Tennantite,!	Hypersthene,	*E, F, G, H,*
Chalcocite,!	Stephanite,	Augite,	*and I.*
Tiemannite,!	Polybasite,!	Spodumene,*	
Millerite,!	Enargite,!	Hornblende,*	
Niccolite,!	Uraninite,!	Actinolite,*	
Pyrite,!	Hübnerite,		
Chalcopyrite,!	*and those in C*		
Linnæite,	*and G.*		

! Completely decomposed or dissolved.
† The CO_2 evolved is derived from the citric acid.
* Feebly attacked.
‡ Gelatinizes.

III.

L. MINERALS NOT DECOMPOSED BY THE ABOVE REAGENTS.

Graphite,	Fibrolite,	Chromite,	Oligoclase.
Molybdenite,	Kyanite,	Chrysoberyl,	Albite.
Diopside,	Topaz,	Cassiterite,	Orthoclase.
Petalite,	Titanite,	Rutile,	Tourmaline.
Asbestus,	Staurolite,	Quartz,	Kaolin.
Beryl,	Bowenite,	Hyalite,	Ripidolite.
Zircon,	Talc,	Muscovite,	Columbite.
Vesuvianite,	Proustite,	Lepidolite,	Samarskite.
Zoisite,	Fluorite,	Wernerite,	Scheelite.
Iolite,	Cryolite,	Leucite,	Barite.
Biotite,	Corundum,	Anorthite,	Celestite.
Andalusite,	Spinel,	Labradorite,	Anhydrite.

(Two hundred species.)

N. B.—The gases evolved are examined with lead acetate paper; the solutions with appropriate reagents.

CHAPTER VII.

CHARACTERISTICS OF THE MOST IMPORTANT ORES: THEIR BEHAVIOR BEFORE THE BLOWPIPE AND WITH SOLVENTS.

Of the physical properties of the minerals which are described in this chapter, only those are enumerated which serve best to discriminate between the different ores from each other. For a more detailed description, the student must refer to Dana's and other works on mineralogy. Among the distinguishing characteristics of minerals, crystalline form, hardness, and specific gravity stand foremost. The latter cannot be ascertained without a balance, and will, for this reason, be of much less use to the practical man than the determination of hardness.

For scales of hardness, fusibility, and systems of crystallization, see pp. 217, 221.

ORES OF ANTIMONY.

200. Stibnite.—Gray Antimony. Sb_2S_3. H.=2; G.=4.5. 71.8 Sb. Trimetric. Of lead-gray color and streak, and metallic lustre. Usually of columnar structure, consisting of a vast number of needle-shaped crystals, sometimes side by side, sometimes divergent. Very brittle.

It fuses readily in the flame of a candle. In a matrass, sometimes yields a slight sublimate of sulphur; on increas-

ing the heat by application of the blowpipe flame, a coating is produced which after cooling is brownish-red, and which consists of a mixture of antimony trisulphide with antimony trioxide. In an open glass tube, emits sulphur dioxide and antimony fumes. On charcoal it is volatilized, covering the charcoal with antimony oxide, which, when touched with the reducing flame, disappears with a pale greenish-blue tinge.

When pure, wholly soluble in hot hydrochloric acid, with evolution of sulphuretted hydrogen; usually a residue of lead chloride is left. Partly decomposed by caustic potash; the solution, when mixed with an acid, affords a yellowish-red precipitate.

201. Berthierite. $FeSb_2S_4$. 57 Sb, 13 Fe. H. = 2–3; G. = 4–4.3. Trimetric. Metallic lustre less splendent than stibnite; color dark steel-gray; surface often covered with iridescent spots.

Heated in a matrass, fuses and yields a slight sublimate of sulphur; on application of a strong heat, a black sublimate of antimony sulphide is formed, which, on cooling, becomes brownish-red. In an open glass tube it behaves like the preceding ore. On charcoal, fuses easily and coats the charcoal with antimony oxide; there remains, finally, a black slag, which is attracted by the magnet and gives with fluxes the iron reaction.

Soluble in hydrochloric acid.

202. Kermesite.—Red Antimony. $2Sb_2S_3 + Sb_2O_3$. 75.3 Sb. H. = 1–1.5; G. = 4.5–4.6. Monoclinic. Usually in tufts of capillary crystals of cherry-red color, with adamantine lustre. Sometimes in thin leaves, flexible and sectile. Streak brownish-red.

In a matrass, fuses readily and yields a slight yellowish-red sublimate; with strong heat, boils and gives a

black sublimate, which when cold is brownish-red. In an open tube and on charcoal, behaves like stibnite.

It dissolves in hydrochloric acid with evolution of sulphuretted hydrogen. The powdered mineral, when treated with caustic potash, assumes an ochre-yellow color and dissolves completely.

Minerals containing antimony: Allemontite, Valentinite, Senarmontite, Cervantite, Livingstonite, etc.

ORES OF ARSENIC.

203. Native Arsenic. As, with traces of Sb, Ag, Au, Fe, and Bi. H.=3.5; G.=5.9. Hexagonal. Of dull metallic lustre; color and streak tin-white, tarnishing on exposure to air to dark-gray.

Heated in a matrass, sublimes; on charcoal, behaves like pure arsenic. In both cases sometimes a residue is left, which, when treated with fluxes, exhibits the reactions of iron, cobalt, and nickel (see par. 99).

204. Orpiment. As_2S_3. As 61. H.=1.5–2; G.=3.4. Trimetric. A foliaceous mineral of lemon-yellow color and streak, and resinous or pearly lustre. Sectile.

Before the blowpipe behaves like the preceding, with this difference, that the sublimate, after cooling, is dark-yellow and transparent.

Soluble in aqua regia and caustic alkalies.

205. Realgar. AsS. 70.1 As. H.=1.5–2; G.=3.4–3.6. Monoclinic. Usually of bright-red, sometimes of orange-yellow color, and resinous lustre. Transparent to translucent; sectile; streak orange.

In a matrass, fuses, boils, and finally sublimes; the sublimate, after cooling, is red and transparent. In an open glass tube, when carefully heated, yields a sublimate of arsenic trioxide, sulphur dioxide escaping. On

charcoal, fuses readily and burns with a yellowish-white flame, emitting grayish-white fumes which possess the peculiar alliaceous odor. Subjected to the treatment described (see par. 70), a sublimate of metallic arsenic is obtained.

Not easily affected by acids, but aqua regia dissolves it with continued digestion, part of the sulphur being precipitated. A hot solution of caustic potash decomposes it, leaving a brownish-black, insoluble powder.

206. Arsenolite.—White Arsenic. As_2O_3. H.=1.5; G.=3.1. Isometric. Occurs usually in minute capillary crystals of a white color and streak, and vitreous or silky lustre.

Before the blowpipe it behaves like pure arsenic trioxide (see pars. 11 and 15, and Table II., 2).

Slightly soluble in hot water; more so in water acidulated with hydrochloric acid.

Minerals containing arsenic: Arsenopyrite, Scorodite, Polybasite, Enargite, Domeykite, Whitneyite, Algodonite, Smaltite, Cobaltite, Niccolite, Pharmacosiderite, Arseniosiderite, etc.

ORES OF BISMUTH.

207. Native bismuth. Bi, with occasional traces of S, As, and Fe. H.=2–2.5; G.=9.7. Hexagonal. Color and streak silver-white tinged with red; lustre metallic; brittle when cold, but when hot may be laminated. Occurs foliated, granular, and arborescent; occasionally crystallized.

Before the blowpipe it behaves like pure bismuth (see pars. 17, 22).

Readily dissolved by nitric acid; the bismuth is precipitated by water.

208. Bismuthinite. Bi_2S_3. 81.25 Bi. H.=2; G.=

6.4–6.55. Trimetric. In acicular crystals or massive, of metallic lustre and lead-gray color, with a yellowish or iridescent tarnish. Streak lead-gray and shiny.

In a matrass, fuses and yields a slight sublimate of sulphur. Carefully heated in an open tube, it fuses and yields sulphur dioxide and a coating of bismuth sulphate; the latter may be fused, by application of the blowpipe flame, to brown drops, which, when cold, appear yellow and opaque. On charcoal, fuses and boils, throwing out small drops in a state of incandescence, and deposits a coating of bismuth trioxide.

Soluble in nitric acid with deposition of sulphur. The solution gives a white precipitate with water.

209. Tetradymite.—Telluric Bismuth. Bi and Te in variable proportions, with sometimes S and Se. 53.61 Bi, 34.48 Te. H. = 1.–25; G. = 7.2–7.9. Hexagonal. Of pale steel-gray color, and high metallic lustre. Occurs usually in tabular crystals or foliated masses; the laminæ are elastic. It soils paper.

In an open glass tube it fuses readily, emitting a white smoke which partly condenses, coating the tube near the assay-piece with a white powder, intermixed with red spots; on directing the flame on this coating, it fuses to colorless drops (tellurium dioxide), while the red sublimate (selenium) disappears. On charcoal, fuses instantly to a metallic globule, which, when touched with the inner flame, imparts a bluish-green color to the outer one, sometimes gives out selenium vapors, and deposits close to the assay-piece a dark orange coating surrounded at a greater distance by a white coating.

Soluble in nitric acid.

210. Bismite.—Bismuth Ochre. Bi_2O_3, containing minute quantities of Fe_2O_3, CuO, and As_2O_5. 89.65 Bi.

G.=4.36. Occurs usually pulverulent or earthy. Streak, straw-colored. Color greenish-yellow to grayish-white.

Before the blowpipe it behaves like pure bismuth trioxide. Soluble in nitric acid.

211. Bismutite. $2Bi_8C_3O_{18} + 9H_2O$. $89.75\,Bi_2O_3$. H.=4–4.5; G.=6.9. Streak usually of a white or light-greenish color; lustre vitreous; in acicular crystallizations.

In a matrass decrepitates, yields a little water, and turns gray. On charcoal, fuses very readily and is reduced, with effervescence, to a metallic globule, covering the charcoal with a coating of bismuth trioxide. If the blast is kept up for some time, the whole of the bismuth is volatilized, and there remains a scoriaceous mass which in the reducing flame may be fused to a globule, and which with fluxes gives the indications of copper and iron. With soda it usually gives the sulphur reaction (see par. 121).

Dissolves in nitric acid with effervescence; also in hydrochloric, giving a solution of yellow color.

Minerals containing bismuth: Maldonite, Joseite, Aikinite, Chiviatite, Emplectite, Wittichenite, Eulytite, Bismutoferrite, etc.

ORES OF CHROMIUM.

212. Chromite.—Chromic Iron. $FeCr_2O_4$, or $(Fe,Mg,Cr)(Al,Fe,Cr)_2O_4$. $68\,Cr_2O_3$. H.=5.5; G.=4.3–4.6. Isometric. Occurs usually massive; of iron-black or brownish-black color, with a shining and somewhat metallic lustre. Some varieties are magnetic. Streak brown.

Heated in a matrass, remains unchanged. Infusible in the forceps. After having been exposed to the reducing flame is attracted by the magnet. In borax and salt of phosphorus, slowly but completely soluble to a transparent glass, which is emerald-green after cooling. Mixed

with soda and nitre and heated on platinum-foil, the mass fuses and becomes yellow. With soda on charcoal in the reducing flame, it yields metallic iron.

Concentrated acids affect it but little, even when finely pulverized; they dissolve only a little iron. Fused with acid potassium sulphate, potassium chromate is formed.

Minerals containing chromium: Crocoite, Melanochroite, Vauquelinite, Wolchonskoite, etc.

ORES OF COBALT.

213. Linnæite.—Cobalt Pyrites. $(Co,Ni)_3S_4$. 58Co. H. = 5.5; G. = 4.8–5. Isometric. Of a more or less bright steel-gray color, and metallic lustre. Streak dark-gray. On charcoal, yields sulphur dioxide and a magnetic globule; often also arsenic fumes. Soluble in nitric acid, giving a rose-red solution.

214. Smaltite.—Smaltine. $(Co,Fe,Ni)As_2$. H. = 5.5–6; G. = 7.4–7.2. Isometric. Of tin-white or steel-gray color and metallic lustre. Streak grayish-black.

In a matrass, usually yields, when heated to redness, a sublimate of metallic arsenic. In an open glass tube, affords a copious sublimate of crystallized arsenic trioxide, and sometimes emits sulphur dioxide. On charcoal it fuses readily, with emission of copious arsenic fumes, to a grayish-black magnetic globule, which, with the fluxes, gives the indications of iron, cobalt, and nickel.

With nitric acid it gives a pink solution, arsenic trioxide being deposited.

215. Cobaltite.—Cobaltine. CoAsS. 35.5Co,45.2As. H. = 5.5; G. = 6–6.3. Isometric. Of silver-white and sometimes reddish color, and metallic lustre. Streak gray.

Unchanged in the matrass. In an open glass tube,

yields a sublimate of arsenic trioxide and vapors of sulphur dioxide. On charcoal, emits copious arsenic and sulphur fumes and fuses to a dull-black metallic globule, which is attracted by the magnet, and which, when treated with fluxes, gives the indications of cobalt and iron, and sometimes also of nickel.

Dissolves in hot nitric acid, arsenic trioxide and sulphur being deposited.

In an open glass tube sulphur dioxide is abundantly evolved, and sometimes a light sublimate of arsenic trioxide formed. On charcoal, small pieces of the mineral readily fuse to a globule, which, when cold, is covered with a black, rough crust, and which is attracted by the magnet. The pulverized mineral, after having been well calcined, dissolves in borax in the oxidizing flame to a blue, transparent bead. In a highly saturated bead of this kind, when treated on charcoal with the reducing flame, particles of metallic nickel may be seen floating about.

216. Asbolite.—Earthy Cobalt. It is a variety of Wad (see par. 273), containing sometimes a considerable quantity of cobalt oxide (40 per cent.), in combination with silica or arsenic.

With borax in the oxidizing flame, gives a dark-violet glass, which in the reducing flame becomes blue. The salt of phosphorus bead, when treated on charcoal with metallic tin, frequently exhibits the copper reaction. With soda on platinum-foil it shows the presence of manganese.

Soluble in hydrochloric acid with evolution of chlorine; the solution is usually blue, and on addition of water becomes rose-red.

Soluble in nitric acid, forming a rose-red solution, the sulphur separating out.

217. Erythrite. — Cobalt Bloom. $Co_3As_2O_8 + 8$ aq. 37·55 Co_2O_3, 38.43 As_2O_5. H. = **1.5–2.5**; G. = **2.9.** Monoclinic. Usually of crimson or peach-red color; when crystallized, of pearly lustre; frequently dull and earthy, forming incrustations. Streak, pale-red.

Heated in a matrass, loses water, and the color changes to blue or green. A small crystal exposed to the inner flame fuses and colors the outer flame pale-blue. On charcoal in the reducing flame, emits arsenic fumes, and melts to a dark-gray globule of cobalt arsenide, which, with fluxes, gives the pure cobalt reactions.

Dissolves readily in acids; the solution is rose-colored; in concentrated hydrochloric acid, appears blue while hot. The pulverized mineral is partly decomposed by caustic potash; the powder assumes a bluish-gray color and the solution is sapphire-blue.

Minerals containing cobalt: Carrollite, Glaucodot, Chathamite, Skutterudite, Alloclasite, Bieberite, Roselite, etc.

ORES OF COPPER.

218. Native Copper.—Pure Copper. H. = **2.5–3**; G. = **8.8.** Isometric. Often twins. Of metallic lustre and copper-red color. Streak metallic, shining, ductile and malleable. Occurs usually massive or arborescent.

It fuses on charcoal to a globule, which, if the heat is sufficiently high, assumes a bright bluish-green surface; on cooling it becomes covered with a crust of black oxide. With the fluxes it gives the usual indications of copper.

It dissolves readily in nitric acid, giving a deep-blue color with ammonium hydrate.

219. Chalcocite.—Vitreous Copper. Cu_2S. 79.8 Cu.

H.=2.5–3; G.=5.5–5.8. Orthorhombic. Of a blackish, lead-gray color, often with a bluish or greenish tint on its surface. Occurs usually in compact masses, very often shining. Streak black; lustre shining.

Heated in a matrass, nothing volatile is given out. In an open tube sulphur dioxide is evolved. On charcoal, readily fuses to a globule, which boils and emits glowing drops, sulphur dioxide escaping abundantly; the outer flame is at the same time colored blue. With soda on charcoal it yields a globule of metallic copper.

Heated with nitric acid, it dissolves, leaving a residue of sulphur.

220. Chalcopyrite.—Copper Pyrite. Cu,FeS_2. 34.6 Cu, 30.5 Fe. H.=3.5–4; G.=4.1–4.3. Tetragonal. Of a brass-yellow color and metallic lustre; on exposure to moist air it becomes iridescent on its surface. It occurs crystallized, but usually massive. Fracture conchoidal, uneven. It is easily scratched with a knife, giving a greenish-black powder.

Heated in a matrass, decrepitates, and yields sometimes a faint sublimate of sulphur, assuming at the same time a darker color or becoming iridescent. Heated in an open glass tube, sulphur dioxide is given out abundantly. On charcoal when heated it blackens, but becomes red on cooling; with continued heat it fuses to a black globule, which is attracted by the magnet; this globule is brittle, and reddish-gray in the fracture. The pulverized mineral, after roasting, gives with the fluxes the reactions of iron and copper. With soda on charcoal it is reduced; the metals are obtained in separate masses. Moistened with hydrochloric acid, it colors the flame green, even previous to fusion.

It dissolves in nitric acid, but more readily in aqua

regia, leaving a residue of sulphur. Same reaction with ammonium hydrate as with other ores of copper.

221. Bornite.—Purple Copper. $FeCu_3S_3$. 55.58 Cu, 16.36 Fe. H. = 3; G. = 5.5. Isometric. When crystalline it usually takes the cubical form, and is of a pale-yellowish color; when massive, its color is copper-red to reddish-brown; it speedily tarnishes, assuming various hues, mostly purple, blue, and red. When scratched with a knife it gives a grayish powder. Streak black.

Before the blowpipe it shows pretty much the same behavior as chalcopyrite.

Concentrated nitric acid dissolves it, leaving the greater part of the sulphur behind.

222. Domeykite.—Arsenical Copper. Cu_3As. 71.7 Cu, 28.3 As. H. = 3–3.5; G. = 7–7.5. Reniform, massive, or disseminated; lustre metallic; color *tin-white* to steel-gray; streak blackish; fracture brittle.

Heated in a matrass, yields a little water and a sublimate of arsenic trioxide; the assay-piece assumes a silver-white color. In an open tube, affords a crystalline sublimate of arsenic trioxide. On charcoal, fuses easily, with emission of a strong alliaceous odor, to a reddish metallic mass, which gives the copper reactions.

Readily soluble in nitric acid. Decomposed by hydrochloric acid, metallic arsenic remaining undissolved.

Algodonite. Cu_6As. 83.5 Cu, 16.5 As. H. = 4; G. = 7.6. Occurs massive; lustre metallic; color *steel-gray;* streak bronze; fracture tough. Same reactions as domeykite. Texture more granular and less malleable than whitneyite.

223. Whitneyite. Cu_9As. 88.4 Cu, 11.6 As. H. = 3.5; G. = 8.3. Massive; lustre metallic; color bronze;

streak bronze; fracture hackly. Same reactions as domeykite and algodonite. Malleable.

224. Enargite. Cu_3AsS_4. 48.4 Cu, 19.1 As. Orthorhombic. H.=3; G.=4–4.3. Color grayish to iron-black; streak grayish-black, powder having a metallic lustre; brittle; easily cleavable; fracture uneven. Fuses on charcoal and gives a faint coating of arsenic, antimony, and generally zinc oxides.

Soluble in aqua regia.

225. Tetrahedrite.—Gray Copper. $4Cu_2S + Sb_2S_3$, or with a portion of the copper replaced by Fe, Zn, Ag, Hg, and the antimony by As or Bi. H.=3–4.5; G.=4.5–5. Isometric; tetrahedral; color and streak between steel-gray and iron-black; lustre metallic.

Heated in a matrass, fuses, and finally yields a dark-red sublimate of antimony trisulphide with antimony trioxide. In an open glass tube, fuses and gives thick fumes of antimony (and arsenic trioxide) and sulphur dioxide. Mercury, when present, condenses in the upper part of the tube, forming a metallic mirror. On charcoal it fuses readily to a globule, emitting thick white fumes and sulphur dioxide; coatings of antimony trioxide and of zinc oxide are deposited; the latter is nearer to the assay-piece, and may be tested with cobalt solution (see par. 54). To detect arsenic, see par. 71; to detect mercury, add to the finely-pulverized assay three times its weight of dry soda and treat the mixture as directed in par. 105. The pulverized mineral, after having been well roasted, gives with the fluxes the indications of iron and copper; with soda, affords metallic copper and a little iron. To detect silver, treat the mineral with pure lead and borax, as directed in par. 119.

When pulverized it is decomposed by nitric acid; the

solution has a brownish-green color; antimony trioxide (and arsenic trioxide) and sulphur remain undissolved. Caustic potash effects a partial decomposition; the antimony trisulphide (and arsenic) enters into solution, and is, on addition of an acid, reprecipitated.

226. Atacamite. $CuCl_2 + 3\,H_2CuO_2$. 59.45 Cu. H. = 3–3.5; G. = 3.7. Trimetric. Occurs crystalline or massive-lamellar; color and streak various shades of bright-green, sometimes blackish-green; streak apple-green; translucent, subtranslucent; lustre vitreous.

Heated in a matrass, gives out water and forms a gray sublimate, which, on cooling, becomes grayish-white; the water shows acid reaction. On charcoal, fuses readily, colors the outer flame azure-blue, and is finally reduced to a globule of metallic copper. Two coatings are deposited on the charcoal, the one grayish-white and the other brownish, which, being played upon with the reducing flame, change their place with an azure-blue tinge.

Easily soluble in acids.

227. Cuprite.—Red Copper. Cu_2O. 88.8 Cu. H. = 3.5–4; G. = 5.8–6. Isometric; cleavage; octahedral; also massive-granular, and sometimes earthy. Usually of a very intense, deep-red color; occasionally crimson-red; often exceedingly friable. Streak red to brownish.

Heated in the forceps, fuses and colors the outer flame emerald-green; moistened with hydrochloric acid and treated in the same manner, the color is azure-blue. On charcoal it blackens, then fuses quietly, and finally yields a globule of metallic copper, which, on cooling, becomes covered with a coating of black oxide.

Dissolves in concentrated nitric acid.

228. Melaconite.—Tenorite. CuO. 79.85 Cu. Earthy, massive, pulverulent (*melaconite*); crystals orthorhombic

(*tenorite*); also in shining, flexible scales. H.=3; G. =6.25. Lustre metallic; color iron-gray when in scales; dull and earthy, with a grayish-black color, and soils the fingers when massive or pulverulent.

Infusible; otherwise reactions like cuprite. Soluble in nitric and hydrochloric acids.

229. Chalcanthite.—Blue Vitriol. $CuSO_4 + 5\,aq$. H. =2.5; G.=2.21. Triclinic; lustre vitreous; color various shades of blue; taste metallic and nauseous; subtransparent, subtranslucent.

Heated in a matrass, swells up, gives out water, and becomes white. On charcoal, colors the outer flame green, fuses, and affords a button of metallic copper, crusted with a coat of sulphide. After calcination, gives, with fluxes, the reactions of copper; sometimes also those of iron.

Soluble in water. A polished plate of iron introduced into the solution becomes coated with copper.

230. Olivenite.—$Cu_3As_2O_8 + H_2CuO_2$. 45.2 Cu. H. =3; G.=4.1–4.4. Trimetric. Crystallized, or in globular and reniform masses of indistinctly fibrous structure. Color and streak usually olive-green to brown; lustre vitreous, adamantine.

In a matrass, yields a little water. In the forceps, fuses to a globule and colors the outer flame bluish-green; the fused mass crystallizes on cooling. On charcoal, fuses, with deflagration and emission of arsenical vapors, to a metallic globule; the globule is white and somewhat brittle, and covered with a brown scoria. Fused with metallic lead, a globule of copper is obtained, and a mass of lead phosphate, which crystallizes on cooling.

Dissolves in nitric acid, also in ammonium hydrate.

231. Tyrolite.—$Cu_5As_2O_{10} + 9\,aq$, with $CaCO_3$. 35 Cu. H.=1–2; G.=3. Trimetric. Usually reniform, mass-

ive; structure radiate foliaceous. Color pale-green. Very sectile. Lustre vitreous.

Heated in a matrass, decrepitates, yields much water, and blackens. On charcoal, fuses with emission of arsenic vapors to a gray scoriaceous mass, in which minute globules of metallic copper occasionally appear. When the mineral is fused on charcoal, with addition of soda and borax, until the copper oxide is completely reduced and the slag dissolved in hydrochloric acid, a solution is obtained in which the presence of lime may be shown by the proper reagents.

Dissolves in nitric acid with effervescence, also in ammonium hydrate, with a residue of calcium carbonate.

232. Malachite. $CuCO_3 + H_2CuO_2$. 57.4 Cu. H.= 3.5–4; G.= 3.7–4. Monoclinic. Occurs usually in the shape of mammillated concretions; the interior is very compact, and lustre shining; in the fracture sometimes earthy, sometimes silky; of a bright-green color, and streak a somewhat paler green.

Heated in a matrass, gives out water and turns black. On charcoal, fuses to a globule, and affords metallic copper when the heat is sufficiently high; heated in the forceps, the outer flame is colored green. With fluxes and soda it behaves like copper oxide (see Table II., 8).

It dissolves in acids with effervescence, and is thus distinguished from other ores of green color; also soluble in ammonium hydrate.

233. Azurite.—Blue Malachite. $2\,CuCO_3 + H_2CuO_2$. 55.2 Cu. H.= 3.5–4.2; G.= 3.5–3.8. Monoclinic. Occurs usually crystallized, or in globular masses of columnar structure. It is easily distinguished by its fine blue color and streak; its earthy, vitreous, and often nearly adamantine, lustre.

Before the blowpipe and with solvents it behaves like malachite.

234. Chrysocolla.—$CuSiO_3 + 2\,aq.$ 45.3 CuO. H.= **2–4**; G.= **2.** Occurs usually as an incrustation. It very much resembles malachite; its color is bluish-green, and it is remarkable for its great compactness; its surface is very smooth, giving it the appearance of an enamel or a well-fused slag. Lustre vitreous. Streak, when pure, white.

In a matrass, yields water and blackens, In the forceps infusible, coloring the outer flame intensely green. On charcoal in the oxidizing flame, blackens; in the reducing flame turns red. Salt of phosphorus and borax dissolve it with the usual indications of copper; the salt of phosphorus bead shows a cloud of undissolved silica. With soda on charcoal, affords globules of metallic copper.

It is decomposed by acids, silica remaining undissolved without gelatinization.

ORES OF GOLD, PLATINUM, AND IRIDIUM.

235. Native Gold.—Combination of Au and Ag in variable proportions, sometimes with traces of Fe and Cu. H.= **2.5–3**; G.= **15.6–19.5.** Isometric. The octahedron and dodecahedron the most common forms. Easily distinguished by its malleability, its cutting like lead, its high specific gravity, and its resistance to acids. Color and streak various shades of gold-yellow, and sometimes almost silver-white. It usually occurs in variously contorted and branched filaments, in scales, in plates, or in small, irregular masses.

On charcoal, fuses to a globule which, after cooling, has a bright metallic surface. With salt of phosphorus

in the oxidizing flame, a bead is formed which opalizes on cooling, or becomes opaque and yellow, according to the amount of silver which it contains.

Resists the action of heated concentrated nitric acid; soluble only in aqua regia.

236. Sylvanite.—Graphic Tellurium. $AgAuTe_3$. H. = 1.5–2; G. = 8–8.3. Monoclinic. Of metallic lustre and steel-gray color. Very sectile. Streak and color pure steel-gray to silver-white; sometimes yellow.

In an open glass tube yields a white sublimate which, when played upon with the flame, fuses to transparent drops. On charcoal, fuses to a dark-gray globule, depositing at the same time a white coating which, when touched with the reducing flame, disappears, tinging the flame bluish-green (see pars. 37, 60). It finally affords a light-yellow, malleable globule of metallic lustre.

Soluble in aqua regia, leaving a residue of silver chloride. The solution gives a white precipitate with water.

Minerals containing gold: Electrum, Maldonite, Nagyagite, Krennerite, Petzite, etc.

237. Native Platinum. Pt, usually combined with a little Fe, Ir, Os, Pd, Rh, and sometimes Cu and Pb. H. = 4–4.5; G. = 16–19. Isometric. Usually occurs in grains of silver-whitish or gray color; malleable and ductile.

Infusible before the blowpipe and not acted upon by fluxes. Soluble only in heated aqua regia. The solution gives a yellow granular precipitate with potassium chloride.

238. Iridosmine.—Osmiridium. Var. 1. Newjanskite. IrOs. G. = 18.8–18.5. Var. 2. Sisserskite. $IrOs_4$, or $IrOs_8$. G. = 20–21.2. Hexagonal. Occurs usually in

irregular flattened grains, of metallic lustre and tin-white color; but little malleable.

Newjanskite is infusible before the blowpipe; when fused with nitre in a matrass the characteristic osmium odor is produced. The fused mass is soluble in water; the solution gives, on addition of nitric acid, a green precipitate. The sisserskite, when strongly heated, gives off the osmium without the addition of nitre, but undergoes no further change.

ORES OF IRON.

239. Native Iron.—Fe. Usually massive, with octahedral cleavage. Color and streak iron-gray. Malleable and ductile. H.=4.5; G.=7.3–7.8. Attracted by the magnet. Occurs in grains disseminated through dolerite, basalt, and other igneous rocks; sometimes in masses. It is a constituent of nearly all meteorites, with variable quantities of Ni (from 1 to 20 per cent.), and traces of Co, Mg, Mn, Sn, Cu, Cr, Si, C, Cl, S, and P. H.=4.5; G.=7.3–7.8.

Infusible. On charcoal, with borax or salt of phosphorus, gives only the reactions of iron. To detect the presence of the other heavy metals, the assay-piece must be dissolved in aqua regia, the liquid mixed with ammonium hydrate in excess, filtered, and the ammoniacal filtrates precipitated with ammonium sulphide. The precipitate consists of the sulphides of nickel, cobalt, manganese, and copper, which may be collected on a filter and treated with borax on charcoal as described par. 99.

240. Pyrite.—Iron Pyrites. FeS_2. 46.7 Fe. H.=6–6.5; G.=4.8–5. Isometric. Occurs commonly in cubes. Usually of a brass-yellow color and metallic lustre; sometimes colored or brown by metamorphosis. By its supe-

rior hardness, not yielding to the knife and emitting sparks when struck with steel, it may be distinguished from copper pyrites. Streak greenish to brownish-black.

Heated in a glass tube closed at one end, usually emits some sulphuretted hydrogen, and yields a sublimate of sulphur; the residue is attracted by the magnet. Heated on charcoal with the oxidizing flame, the sulphur burns off with a blue flame and leaves red oxide behind, which, when treated with the fluxes, gives pure iron reactions. But slightly affected by hydrochloric acid; nitric acid dissolves it, leaving a residue of sulphur.

241. Marcasite.—White Iron Pyrites. FeS_2. H.=6–6.5; G.=4.6–4.8. Trimetric. Crystals are prismatic, often twins. Color usually light bronze-yellow, sometimes inclined to green or gray; occurs frequently in radiated masses or crest-like aggregations; streak greenish-gray. Very liable to decomposition.

Before the blowpipe it behaves like the preceding.

242. Pyrrhotite.—Magnetic Pyrites. Fe_7S_8. 60.5 Fe. H.=3.5–4.5; G.=4.4–4.7. Hexagonal. Very much resembles common iron pyrites, from which it is distinguished by its inferior hardness, more reddish color, quickly tarnishing, and by being slightly attracted by the magnet. Streak dark grayish-black.

Heated in a matrass, remains unchanged; in the open glass tube, emits sulphur dioxide, but yields no sublimate. On charcoal in reducing flame, fuses to a globule, which is covered with an uneven black coating, which follows the magnet, and which, on a surface of fracture, exhibits a yellowish crystalline structure and metallic lustre. In the oxidizing flame it is converted into red oxide.

Soluble in hydrochloric acid, excepting the sulphur, with evolution of sulphuretted hydrogen.

243. Arsenopyrite.—Mispickel. $FeS_2 + AsS_2$. 34.4 Fe. 68 As. H. = 5.5–6; G. = 5–6.4. Trimetric. Of metallic lustre and a silver-white to steel-gray color. Streak dark grayish-black. Brittle.

Heated in a matrass, yields first a red sublimate of arsenic sulphide, and afterward a black crystalline one of metallic arsenic; in an open glass tube yields arsenic trioxide and sulphur dioxide. On charcoal, emits copious arsenic fumes, and a coating of arsenic trioxide is deposited; then fuses to a globule which shows the properties of fused pyrrhotite. Frequently contains cobalt, the presence of which may be detected by the method described in par. 99. May be distinguished by its orthorhombic form from smaltite.

Soluble in nitric acid and aqua regia, leaving a residue of sulphur and arsenic trioxide; the latter dissolves with continued digestion.

244. Hematite.—Specular Iron. Fe_2O_3. 70 Fe. H. = 5.5–6.5; G. = 4.5–5.3. Hexagonal. Of a dark steel-gray or iron-black color, and usually of metallic lustre; its powder and streak are red. Fracture subconchoidal, uneven.

Alone infusible; becomes magnetic after roasting, and gives the usual indications of iron with the fluxes; its powder dissolves readily heated with hydrochloric acid. Sometimes contains chromium and titanium, which may be detected by the processes given in pars. 85 and 125.

245. Menaccanite.—Titaniferous Iron. $(TiFe)_2O_3$ or Ti_2O_3, and Fe_2O_3 in various proportions. H. = 5–6; G. = 5.5–6. Hexagonal. Of iron-black color, usually in tabular crystals; slightly attracted by the magnet. It resembles magnetite.

Alone in the oxidizing flame, infusible; in reducing flame it may be rounded at the edges. With borax and salt of phosphorus in oxidizing flame gives the reactions of pure iron oxide; but the salt of phosphorus bead, when treated with the reducing flame, assumes a brownish-red color, the intensity of which depends upon the amount of titanium oxide present; this glass, when treated with tin on charcoal, turns violet (v. Table II., par. 31). To show conclusively the presence of Ti, follow the method given in par. 125.

Dissolved by hydrochloric acid and aqua regia, with separation of titanium oxide; some varieties dissolve with great difficulty, even when reduced to a very fine powder.

246. Magnetite.—Magnetic Iron Ore. Fe_3O_4. 72.4 Fe. H.=5.5–6.5; G.=4.9–5.2. Isometric. Its color is iron-black, with a shining metallic or glimmering lustre; its powder and streak are black; it is strongly attracted by the magnet.

It fuses with difficulty, and gives the usual reactions of iron with the fluxes; the pulverized mineral dissolves completely in hydrochloric acid.

247. Franklinite. (Fe,Zn,Mn), Fe,MnO_4, usually with a little SiO_2,Al_2O_3. H.=5.5–6.5; G.=5. Isometric; habit octahedral; occurs crystallized, massive, granular to compact; lustre metallic; color iron-black; streak dark reddish-brown; fracture conchoidal, brittle; acts slightly on the magnet.

Infusible. Dissolves in borax and salt of phosphorus with manganese reaction. The borax bead, when treated on charcoal in the reducing flame, becomes bottle-green; with soda on platinum-foil, gives manganese reaction; with soda on charcoal, gives a faint coating of zinc

oxide, which becomes more distinct on addition of a mixture of borax and soda.

Dissolves completely in heated hydrochloric acid to a greenish-yellow liquid, a small amount of chlorine being evolved.

The zinc is easily obtained by neutralizing the acid solution of the mineral, acidifying with acetic acid, and adding sulphuretted hydrogen. (*Leeds.*)

It resembles magnetite, but gives the zinc coating on charcoal, and is not as strongly attracted by the magnet.

248. Limonite.—Brown Hematite. $H_6Fe_2O_9$. 59.9 Fe. H.=5–5.5; G.=3.6–4. Of a dull brownish-yellow color to black, earthy or semi-metallic in appearance, and often in mammillary or stalactitic forms. Streak yellowish-brown.

In a matrass yields water, and red sesquioxide remains; in platinum forceps, fusible on the edges; gives with borax and salt of phosphorus an iron reaction; the clayey varieties, treated with salt of phosphorus, give a cloud of undissolved silica; treated with soda and nitre on platinum-foil, the manganese reaction is almost always obtained.

249. Göthite. H_2FeO_4. 89.9 Fe_2O_3, 10.1 H_2O. Orthorhombic. In striated prisms, scales, and tabular; also fibrous, foliated, massive, stalactitic, and reniform. H.=5–5.5; G.=4–4.4. Lustre imperfect adamantine; color yellowish, reddish, and blackish-brown; streak brownish to ochre-yellow.

In the closed tube gives off water, and is changed into red sesquioxide. Behaves like hematite, with fluxes.

Soluble in hydrochloric acid.

250. Turgite. $H_2Fe_2O_7$. 94.7 Fe_2O_3, 5.3 H_2O. H.=5–

6; G.=3.56–4.14. Lustre sub-metallic, also dull earthy; color reddish-black to dark-red; bright-red when earthy; botryoidal surface; often lustrous, like limonite.

Heated in a closed tube, flies to pieces with violence, and yields water. Otherwise like hematite.

Its superior hardness, color of its streak, and decrepitation before the blowpipe distinguish it from hematite and limonite.

251. Melanterite. — Copperas. $FeSO_4 + 7aq.$ 25.9 FeO. H.=2; G.=1.8. Monoclinic. Occurs usually massive and pulverulent, of various shades of green, becoming yellowish on exposure to air; taste astringent and metallic.

In a matrass gives out sulphur dioxide and water, which shows acid reaction. Strongly heated, only sesquioxide of iron remains. Soluble in water.

252. Vivianite. — Blue Iron Earth. $Fe_3P_2O_8 + 8aq.$ H.=1.5–2; G.=2.6. Monoclinic. Occurs crystallized, or in reniform and globular masses, fibrous, and radiated; sometimes as incrustation; color white, to blue or green; usually dirty blue; vitreous lustre and bluish-white streak, which often changes quickly to indigo-blue.

In a matrass swells and gives off water. In the forceps, fuses to a steel-gray metallic globule, coloring the outer flame bluish-green. With fluxes gives the reactions of iron.

Easily soluble in hydrochloric acid and nitric acid. With a solution of caustic potash, it blackens.

Beraunite is of similar character, occurring in small foliated, columnar masses. H.=2; G.=2.8. Color hyacinth-red to reddish-brown; streak dirty-yellow.

253. Scorodite. $FeAs_2O_8 + 4aq.$ 24.22 Fe, 32.52 As. H.=3.5–4; G.=3.1–3.3. Trimetric; crystallized; color

pale leek-green or liver-brown; lustre vitreous; streak white.

In a matrass yields pure water, and turns yellow. In the forceps, fuses to a gray scoriaceous slag of metallic lustre, coloring the outer flame pale-blue. On charcoal, emits arsenic vapors, and fuses to a gray magnetic slag of metallic lustre, which gives with fluxes the reactions of iron.

Not affected by nitric acid; forms a brown solution with hydrochloric acid; partially dissolved by ammonium hydrate, leaving a brown residue.

254. Siderite.—Spathic Iron. $FeCO_3$. 48.22 Fe. H. = 3.5–4.5; G. = 3.7–3.9. Hexagonal; color from grayish-yellow to reddish-brown; crystallizes in rhombohedrons, which are often curved, and are very distinctly cleavable; often massive; lustre vitreous; and streak light-brown.

Heated in a matrass, frequently decrepitates, carbon dioxide and carbon monoxide are given out, and a black iron oxide remains, which is attracted by the magnet. Alone infusible. With borax and salt of phosphorus it gives the pure iron reactions, and with soda sometimes those of manganese. Heated with strong acid, it dissolves readily, with brisk effervescence, but slowly in the cold.

Minerals containing iron: Chromite, Wolframite, Columbite, Tantalite, Dufrenite, Cacoxenite, Triphylite, Lölingite, Leucopyrite, etc.

ORES OF LEAD.

255. Galenite. PbS. 86.6 Pb. H. = 2.5–2.75; G. = 7.25–7.7. Isometric; color and streak lead-gray; of metallic lustre. Crystals usually cubical, with very perfect cubic cleavage. Octahedrons and twins not uncommon. It is generally argentiferous.

Heated in a matrass, sometimes decrepitates, and frequently yields a slight white sublimate. Heated in an open glass tube, emits sulphur dioxide, and, the heat being raised, gives a white sublimate of lead sulphate. Heated on charcoal, affords a globule of pure lead, the charcoal becoming at the same time covered with lead sulphate and lead oxide. The globule of metallic lead yields generally a little silver on cupellation. The presence of antimony is ascertained as shown in par. 64; zinc, par. 129; iron, par. 99, *b*.

It dissolves with some difficulty in dilute boiling hydrochloric acid, with evolution of sulphuretted hydrogen. Very dilute nitric acid has no effect on it, but by a stronger acid it is readily dissolved, with evolution of nitrogen tetroxide. By fuming nitric acid and aqua regia it is very violently acted upon, being converted into sulphate or a mixture of the sulphate with the chloride.

256. Bournonite. $2\,PbS + Cu_2S$. 42.4 Pb, 25 Sb, 13 Cu. H. = 2.5–3; G. = 5.7–5.9. Trimetric. Occurs crystallized, and massive, granular, compact; lustre metallic; color and streak steel-gray.

In a matrass, decrepitates, and yields with a strong heat a dark-red sublimate. In an open tube, sulphur dioxide is evolved, and abundant antimony fumes, which condense partly on the upper and partly on the lower side of the tube; the upper of antimony trioxide, which is volatile; the lower is not volatile, and consists of a mixture of antimony tetroxide, Sb_2O_4, with lead antimonate. On charcoal, fuses readily to a black globule and deposits a coating of antimony trioxide; with strong heat a coating of lead oxide is obtained; the remaining globule, when treated with borax in the oxidizing flame,

gives the reactions of copper, and the globule assumes the appearance of metallic copper.

Dissolves readily in nitric acid to a blue liquid, leaving a residue of antimony trioxide and sulphur. Aqua regia leaves a residue of sulphur, lead chloride, and lead antimonite; the solution gives a precipitate with water.

The following ores behave before the blowpipe in a very similar manner:

Geocronite. $Pb_5S + Sb_2S_8$. 15.9 Sb, 67.4 Pb. Sometimes with a little arsenic. Color lead-gray; granular. Trimetric.

Dufrenoysite. $2\,PbS + 2\,As_2S_3$. 57.18 Pb, 20.72 As. Color blackish, lead-gray; streak reddish-brown. Opaque; brittle. Trimetric.

Boulangerite. $3\,PbS + Sb_2S_3$. 58.7 Pb, 23.1 Sb. Color bluish lead-gray, often spotted with red. Crystalline and granular. Orthorhombic.

Jamesonite. $2\,PbS + Sb_2S_3$. 32.2 Sb, 43.7 Pb. Also containing Fe. Oxidized by nitric acid to a white powder, imparting no color to the solution. Trimetric.

Plagionite. $4\,PbS + 3\,Sb_2S_3$. Monoclinic.

Zinkenite. $PbS + Sb_2S_3$. Trimetric.

Meneghenite. $4\,PbS + Sb_2S_3$. Monoclinic.

Those minerals in which a part of the Sb_2S_2 is substituted by As_2S_3 give on charcoal arsenical vapors, and in an open tube a crystalline sublimate.

257. Minium. $Pb_3O_4Pb = 90.66$. H. = 2–3; G. = 4–6. Pulverulent. Color vivid red mixed with yellow.

Before the blowpipe, behaves like lead oxide.

With hydrochloric acid, evolves chlorine and is converted into lead chloride. With nitric acid becomes brown.

258. Massicot.—Plumbic Ochre. PbO, often with Pb CO_3, CaO, Fe_2O_3, and SiO_2. 92.83 Pb. H. = 2; G. = 8. Trimetric; also isometric. Massive. Lustre dull; color between sulphur- and orpiment-yellow. Streak light-yellow.

Before the blowpipe, behaves like lead oxide.

259. Anglesite.—Lead Vitriol. $PbSO_4$. 68.3 Pb. H. = 2.75–3; G. = 6.2. Trimetric. It often occurs in small octahedral crystals with many facets, but more frequently in lamellar masses; of high adamantine lustre; also massive and granular. Fracture conchoidal. Very brittle.

Heated in a matrass, decrepitates and usually yields a little water. Treated on charcoal in the oxidizing flame, fuses to a clear bead, which, on cooling, turns milk-white; with soda on charcoal, affords a globule of metallic lead; the soda is absorbed by the charcoal, and shows, when placed on silver-foil, a strong sulphur reaction. With the fluxes, gives the reactions of lead oxide. Traces of iron or manganese may be detected by borax or soda, as shown in pars. 99, *d*, and 104.

It dissolves in acids only with great difficulty and without effervescence; by hydrochloric acid it is partly decomposed; the pulverized mineral is soluble in a solution of caustic potash.

260. Crocoite.—Red Lead Ore. $PbCrO_4$. 63.2 Pb. H. = 2.5–3; G. 5.9–6.1. Monoclinic. Occurs usually in bright hyacinth-red crystals of adamantine lustre. Streak orange. Translucent. Sectile.

In a matrass, decrepitates; the crystals are broken up into minute pieces and assume a darker color. On charcoal fuses and becomes reduced with detonation; a coating of lead oxide is formed, and grayish-green chro-

mium sesquioxide remains with the metallic globule. With soda on charcoal, affords a globule of metallic lead. With soda on platinum-foil, fuses to a dark-yellow mass, which becomes green in the reducing flame. With borax or sodium phosphate in the oxidizing flame, dissolved; the bead appears yellow while hot, but becomes green on cooling. Fused in a platinum spoon with from three to four parts of acid potassium sulphate, gives a dark-violet mass, which is greenish-white when cold.

261. Vauquelinite. $Pb_2CuCr_2O_9$. 56.4 Pb, 8.6 Cu. H. = 2.5–3; G. = 5.5–5.7. Monoclinic. Occurs usually in minute crystals, or in reniform or globular masses. Color dark-green to brown, sometimes nearly black. Lustre adamantine to resinous; streak greenish to brownish.

On charcoal, fuses with effervescence to a gray, submetallic globule; where the mass is in contact with the coal, small globules of lead make their appearance; in the reducing flame, a coating of lead oxide is formed. With borax or sodium phosphate in the oxidizing flame, clear green beads are obtained, which remain green on cooling, but which, on application of the reducing flame, become red and opaque; this reaction appears most distinctly on charcoal with tin. With soda on platinum wire in the oxidizing flame, dissolves to a transparent green bead, which on cooling becomes yellow and opaque; on treating the bead with a few drops of water, a yellow solution is obtained, in which the presence of chromic acid may be proved, as described in par. 68. With soda on charcoal, is completely decomposed; on treating the reduced metals with boric acid on charcoal (see par. 88), a globule of metallic copper is obtained.

Partly soluble in nitric acid to a dark-green liquid; the residue is yellow.

262. Wulfenite.—Yellow Lead Ore. $PbMoO_4$, sometimes with a little Cr. 57.Pb. H.=**2.75–3**; G.=**6.9.** Dimetric. Crystallized or granularly massive, firmly coherent. Color usually wax-color, passing into orange-yellow. Streak white.

In a matrass, decrepitates and becomes darker while hot. On charcoal, fuses and is partly absorbed by the coal, while metallic lead and a coating of lead oxide are deposited. With borax or sodium phosphate on platinum wire, gives the reactions of molybdic acid (see Table II., 18). With soda on charcoal, affords a globule of metallic lead. Fused with acid potassium sulphate in a platinum spoon, a yellowish mass is obtained, which becomes white on cooling; treated with distilled water and a piece of metallic zinc placed in the solution, the liquid assumes a blue color. Moistened with sulphuric acid, heated in the platinum spoon or on foil until dense fumes escape, allowed to cool, and then breathed upon, it changes to a deep-blue color.

Dissolves in concentrated hydrochloric acid to a green liquid, leaving a residue of lead chloride. The pulverized mineral is decomposed on being digested with nitric acid; a yellowish-white residue is left, which becomes blue when exposed to air in thin layers.

263. Pyromorphite. $3Pb_3(PO_4)_2 + PbCl_2$ Very frequently the P is replaced by As and the Pb by Ca. 76.2 Pb. H.=**3.5–4**; G.=**6.5–7.** Hexagonal. It occurs often in globular masses with a columnar structure, also reniform, fibrous, and granular. Lustre adamantine. Streak slightly yellow. Color green, yellow, and brown of different shades; also white.

Heated in a matrass, sometimes decrepitates and yields, with continued heat, a faint white and volatile sublimate

of lead chloride. Heated in the platinum-pointed forceps, fuses readily and colors the outer flame bluish-green; if the amount of phosphoric acid is not too small, the edges of the flame will appear green. With salt of phosphorus and copper oxide, gives the reaction for chlorine (par. 82). On charcoal in the oxidizing flame, fuses to a globule, which, on cooling, assumes a polyhedral form and a dark color; in the reducing flame, yields a coating of lead oxide, and the globule, on cooling, assumes dodecahedral facets of pearly lustre. With magnesium wire, gives the reaction for phosphoric acid (par. 110). With soda on charcoal, affords metallic lead. When a portion of the phosphorus is replaced by arsenic, it is readily detected by the odor when treated with soda on charcoal (par. 33). Also a part of the lead is replaced by calcium, as in the brown varieties polysphærite, miesite, and nussierite, while some of the PbCl is replaced by calcium fluoride, thus diminishing the amount of lead.

Soluble in nitric acid and solution of caustic potash.

264. Plumbo-Gummite. Contains Al_2O_3,Pb,H_2O,P_2O_5. H.=4–5; G.=4.8–6.4. In reniform or globular masses, with a columnar structure; also compact, massive. Of resinous lustre; color white, grayish-green, reddish-yellow, but usually yellowish-brown; resembling gum-arabic in appearance. Streak colorless.

In a matrass, decrepitates and gives out water. In the forceps, intumesces and colors the outer flame azure-blue. On charcoal, intumesces, becomes white and opaque, and fuses but imperfectly, depositing a faint white coating of lead chloride. In small quantities, soluble in borax and salt of phosphorus to clear beads. With soda on charcoal, minute globules of metallic lead are obtained.

Treated with cobalt solution, assumes a fine blue color. Soluble in nitric acid. The solution gives with ammonium molybdate a yellow precipitate.

265. Cerussite.—White Lead Ore. $PbCo_3$ 77.8 Pb. H. = 3–3.5; G. = 6.4. Trimetric. Occurs granularly massive, in prismatic needles, or in compressed plates. Rarely fibrous. Color mostly white, yellow or gray. Streak colorless.

When heated in a matrass decrepitates and turns yellow; carbon dioxide is given out. Heated on charcoal alone, is reduced to a metallic bead. Treated with fluxes, dissolves with effervescence and gives the reactions of pure lead oxide (see Table II., 15); dissolves readily and with effervescence in dilute nitric acid; with hydrochloric acid, leaves a residue of lead chloride; dissolves in a solution of caustic potash.

266. Leadhillite. $PbOSO_4 + 3\,PbCO_3$. 75. Pb. H. = 2.5; G. = 6.2–6.5. Trimetric. Occurs in transparent crystals of pearly or resinous lustre. Color white, passing into yellow, green, or gray. Streak white.

On charcoal, intumesces slightly, becomes yellow, but white again on cooling; with greater heat easily reduced to metallic lead.

Dissolves in nitric acid with effervescence, leaving a residue of lead sulphate. **Lanarkite** is closely related.

267. Phosgenite. $PbCl_2 + PbCO_3$. 73.8 Pb. H. = 2.75–3; G. = 6–6.3. Dimetric. Forms crystals of adamantine lustre, of white, gray, or yellow color. Streak white. Transparent and translucent. Somewhat sectile.

In a matrass, decrepitates slightly and becomes a little darker yellow. On charcoal, fuses readily, emits acid vapors, becomes reduced to metallic lead, and gives a

white coating of lead chloride and a yellow coating of oxide. With salt of phosphorus and copper oxide gives the chlorine reaction.

Dissolves in nitric acid with effervescence.

Minerals containing lead: Clausthalite, Mendipite, Caledonite, Mimetite, Vanadinite, Melanochroite, Stolzite, etc.

ORES OF MANGANESE.

268. Pyrolusite.—Black Oxide of Manganese. MnO_2. 63.3 Mn. H. = 2–2.5; G. = 4.8. Trimetric. Of black or steel-gray color and little lustre; powder black; sometimes of columnar structure. Streak black or bluish-black; sometimes sub-metallic. It is distinguished from psilomelane by its inferior hardness and being usually crystalline.

In a matrass, usually yields a little water; when heated to redness, oxygen is evolved. Alone infusible, but turning reddish-brown when the temperature is sufficiently high. Soluble in borax and salt of phosphorus with the usual manganese reactions; gives frequently the indications of iron.

Soluble in hydrochloric acid with disengagement of chlorine.

269. Hausmannite. Mn_3O_4. 72.1 Mn. H. = 5–5.5; G. = 4.7. Dimetric. Crystallized or granular particles, strongly coherent. Color brownish-black; streak chestnut-brown.

Before the blowpipe and with hydrochloric acid behaves like the preceding ore.

270. Braunite. $2(2\,MnO, MnO_2) + MnO_2, SiO_2$. H. = 6–6.5; G. = 4.7–4.8. Dimetric. Occurs crystallized or massive; color and streak brownish-black.

In a matrass *does not give any water;* behaves other-

wise like pyrolusite. Dissolves in hydrochloric acid, with disengagement of chlorine, leaving sometimes a residue of silica. Distinguished from the preceding ores of manganese by its superior hardness.

271. Manganite. H_2MnO_4. 89.8 MnO_3, 10.2 H_2O. H. = 4; G. = 4.2–4.4. Trimetric; columnar; seldom granular; often stalactitic; lustre sub-metallic; color dark steel-gray to iron-black; streak reddish-brown to nearly black; opaque; fracture uneven.

In the closed tube yields water; otherwise similar to braunite.

272. Psilomelane. Composition very doubtful; essentially MnO_2, with BaO, or K_2O and H_2O. H. = 5–6; G. = 3.7–4.3. Massive, botryoidal, and stalactitic; color iron-black to steel-gray; streak brownish-black, shining.

In a matrass it usually *yields considerable water*. With solvents it behaves like pyrolusite.

273. Wad.—Bog Manganese. Essentially $2MnO_2 + H_2O$; and also often contains FeO_3, AlO_3, BaO, SiO_2, etc. H. = 0.5–6; G. = 3–4.2. Amorphous, earthy, or compact; of a dull-black color.

Varieties:

a. Bog Manganese, manganesian.

b. Asbolite, cobaltiferous.

c. Lampadite, cupriferous.

Before the blowpipe—

a. Behaves like psilomelane.

b. Gives a blue bead with salt of phosphorus, and, when heated in the reducing flame on charcoal, with addition of Sn, sometimes gives a copper bead, red and opaque.

c. Gives similar reactions to the last, and some varieties the manganese reaction with soda, and gives off chlorine when treated with hydrochloric acid.

274. Rhodochrosite.—Dialogite. $MnCO_3$; the Mn often replaced in part by Ca, Mg, Fe, or Co. H. = 3.5–4.5; G. = 3.4–3.7. Hexagonal. Occurs crystallized or in globular masses of columnar structure; also massive; color shades of rose-red to brownish-red; streak white; lustre vitreous and inclined to pearly; translucent; subtranslucent.

In a matrass, some varieties give a little water, and decrepitate violently. Infusible. When heated in the reducing flame, does not become magnetic. Dissolves in fluxes with effervescence, and gives usually the reaction of manganese and iron.

The pulverized mineral is little affected by hydrochloric acid in the cold; on heating, dissolves with effervescence.

275. Rhodonite. $MnSiO_3$. 54.1 MnO, 45.9 SiO_2. H. = 5.5–6.5; G. = 3.4–3.7. Triclinic; usually massive; lustre vitreous; brownish-red, flesh-red, yellowish-red, or black on the surface from exposure; streak uncolored.

When heated becomes dark-brown, and gives to borax a deep violet while hot and reddish-brown when cold.

Resembles red feldspar, but differs in specific gravity, blackening on exposure, and coloring the borax bead.

Minerals containing manganese: Franklinite, Wolframite, Alabandite, Hauerite, Chalcophanite, Lithiopholite, Triphylite, Triplite, Dickinsonite, Reddingite, Fairfieldite, Triploidite, etc.

ORES OF MERCURY.

276. Native Mercury. Hg; sometimes containing a little Ag. G. = 13.5. Metallic globules of a tin-white color.

Heated in a matrass, is converted into vapor, which condenses in the neck of the matrass to small metallic globules.

Dissolves readily in nitric acid.

Amalgam. AgHg, 64.9 Hg, and also Ag_2Hg_3. 73.5 Hg. H. = 3–3.5; G. = 13.5–14. Isometric. Occurs crystallized and massive. Color and streak silver-white; opaque.

In a matrass, boils, gives a sublimate of metallic mercury, and leaves a spongy residue of silver, which on charcoal fuses readily to a globule.

Dissolves readily in nitric acid.

Arquerite. $Ag_{12}Hg$. 13.4 Hg. G. = 10.8. Isometric. In regular octahedrons; also in grains, small masses, and sometimes dendritic. In color, lustre, and ductility like native silver, but softer.

277. Cinnabar. HgS. H. = 2–2.5; G. = 8.98. Hexagonal; color various shades of red, from cochineal-red to dark brownish-red; powder always bright red. It occurs in very small flattened crystals, or granularly massive. Streak scarlet, subtransparent to opaque.

Heated in a matrass, is volatilized, and condenses to a black sublimate, which by friction sometimes assumes a red color. Mixed with soda, yields, on heating, globules of metallic mercury. In an open glass tube is partially decomposed into metallic mercury and sulphur dioxide. On charcoal it is, when pure, wholly volatilized.

Nitric acid and hydrochloric acid have no visible effect on it. Aqua regia dissolves it, part of the sulphur being precipitated. Insoluble in caustic potash.

278. Calomel.—Horn Quicksilver. HgCl. 84.9 Hg. H. = 1–2; G. = 6.48. Dimetric. Occurs usually in distinct crystals, or crystalline coats, of adamantine lustre and yellowish-gray color. Translucent; streak pale yellowish-white.

In a matrass, yields a white sublimate of mercurous chloride. Mixed with soda and heated in a matrass, af-

fords globules of metallic mercury. On charcoal, completely volatilizes, giving a white coating. Shows the chlorine reaction when treated as described in par. 82. Treated with boiling hydrochloric acid, is partly dissolved, and becomes gray. Not affected by nitric acid; dissolved by aqua regia. With a solution of alkali, becomes black.

Minerals containing mercury: Metacinnabarite, Tiemannite, Coloradoite, Magnolite, etc.

ORES OF NICKEL.

279. Millerite. — Capillary Pyrites. NiS. 64.4 Ni. H. = 3–3.5; G. = 4.6–5.6. Hexagonal. Occurs usually in delicate capillary crystals of brass-yellow to bronze-yellow color, often with gray iridescent tarnish, and metallic lustre. Streak bright. Brittle.

In an open glass tube evolves sulphur dioxide. On charcoal, fuses with emission of sparks to a metallic globule which is attracted by the magnet. The calcined mineral gives with fluxes the indications of nickel oxide, and sometimes also those of cobalt oxide.

By heated concentrated nitric acid it is but little affected, but its color is changed to gray. By aqua regia it is wholly dissolved.

280. Niccolite. — Copper Nickel. NiAs, or Ni_3As_3. 43.6 Ni, 56.4 As. Sometimes part of the As is replaced by antimony. H. = 5–5.5; G. = 7.3–7.6. Hexagonal. Usually massive; of copper-red color, with a gray tarnish and metallic lustre; very brittle. Streak dark-brown.

In a matrass affords a very slight sublimate of arsenic trioxide. In an open glass tube yields a copious sublimate of arsenic trioxide, and usually a little sulphur

dioxide; the assay-piece assumes at the same time a yellowish-green color and crumbles to powder. On charcoal, emits arsenic fumes and fuses to a white and brittle globule, which, when treated with borax in the oxidizing flame, imparts usually to the flux the colors of iron and cobalt. Sometimes a faint coating of lead oxide is deposited on the charcoal.

Dissolves almost completely in concentrated nitric acid; the solution has a green color; on cooling, arsenic trioxide separates. Readily dissolved by aqua regia.

281. Gersdorffite.—Nickel Glance. $NiS_2 + NiAs_2$. 35.2 Ni, 45.5 As. H. = **5.5**; G. = **5.6–6.9.** Isometric; pyritohedral. Of silver-white or steel-gray color and metallic lustre. Streak grayish-black.

In a matrass, decrepitates violently, and yields a yellowish-brown sublimate of arsenic sulphide. In an open glass tube, emits arsenic trioxide and sulphur dioxide. On charcoal, fuses with emission of sulphur and arsenic fumes to a globule, which, when treated with borax in the reducing flame, gives the reactions of iron and cobalt. After having removed these two metals, the remaining globule exhibits with the fluxes the reactions of pure nickel oxide.

Partly decomposed by nitric acid, giving a green solution, sulphur and arsenic trioxide being separated.

282. Ullmannite.—Nickeliferous Gray Antimony. $NiS_2 + NiSb_2$. 27.7 Ni. Arsenic is sometimes present. H. = **5–5.5**; G. = **6.2–6.5.** Isometric. It closely resembles the preceding ore in its physical properties. Streak dark steel-gray.

In a matrass, yields a slight white sublimate. In an open glass tube, emits copious antimony fumes and sulphur dioxide. On charcoal in the reducing flame, fuses

to a globule and coats the charcoal with antimony trioxide; sometimes the odor of arsenic is observable. The melted globule, when treated with borax, frequently exhibits the reactions of iron and cobalt besides those of nickel.

It is violently acted upon by concentrated nitric acid, forming a green solution, sulphur, antimony, and arsenic trioxides being precipitated. Aqua regia dissolves it, the sulphur separating out.

283. Annabergite. $Ni_3As_2O_8 + 8\,aq.$ 29.2 Ni. Monoclinic. Soft, earthy. In capillary crystals, also massive and disseminated. Color fine apple-green. Streak somewhat lighter.

In a matrass, yields water and darkens in color. In the forceps, fuses easily and colors the outer flame light-blue. On charcoal in the reducing flame, fuses with emission of arsenic vapor to a blackish-gray globule; when treated with borax the globule gives the reactions of nickel, sometimes also those of iron and cobalt, which it always contains.

Soluble in acids, giving a green solution.

284. Zaratite.—Emerald Nickel. $Ni_3CO_5 + 6\,aq.$ 59.3 NiO. H.=3–3.2; G.= 2.5–2.7. Usually forms incrustations of emerald-green color and vitreous lustre. Streak pale-green.

In a matrass, loses already at 212° a considerable amount of water, and blackens. In borax and salt of phosphorus, dissolves with effervescence, exhibiting the characteristic nickel reactions.

Dissolves easily in heated dilute hydrochloric acid with effervescence.

285. Genthite. $H_4(Ni,Mg)_4Si_3O_{12}$. Amorphous. Incrusted with a delicate stalactitic surface. H.=3–4.

Some specimens very soft, and, if placed in water, crumble to pieces. G.=2.409. Lustre resinous; color yellowish or greenish. Streak greenish-white. Translucent to opaque.

In the closed tube, blackens and yields water. Infusible before the blowpipe. Gives a violet bead in the oxidizing flame, gray in the reducing flame.

Decomposed by hydrochloric acid without gelatinizing.

Minerals containing nickel: Beyrichite, Breithauptite, Morenosite, etc.

ORES OF SILVER.

286. Native Silver.—Pure silver, associated with gold, copper, and sometimes platinum, antimony, bismuth, and mercury. H.=2.5–3; G.=10–11. Isometric; twins. Color silver-white; lustre metallic; ductile and malleable. Occurs usually in twisted filaments, or arborescent; sometimes in plates or massive.

On charcoal, fuses easily to a globule, which assumes a bright surface, and shows after cooling a silver-white color. Foreign metals are detected by the methods given in pars. 117–119.

It dissolves in nitric acid, and is again deposited by a plate of copper.

287. Argentite.—Silver Glance. Ag_2S. 87.1 Ag. H. =2–2.5; G.=7. Isometric. Color blackish, lead-gray; lustre metallic. It is easily distinguished from other minerals of the same color by being cut with a knife like lead. Malleable.

On charcoal in the oxidizing flame, intumesces, gives out sulphur dioxide, and finally yields a globule of metallic silver.

Soluble in dilute nitric acid, leaving a residue of sulphur.

Jalpaite. $(Ag_2Cu_2)S$. Isometric. A cupriferous silver glance from Mexico. Color blackish lead-gray. Malleable.

Acanthite. Ag_2S. Trimetric. Reactions the same as for argentite, and differs only in crystalline form.

288. Stromeyerite.—Argentiferous Sulphide of Copper. $Cu_2S + Ag_2S$. 53 Ag, 31.2 Cu. H. = 2.5–3; G. = 6.2–6.3. Trimetric. Occurs usually in small, compact masses. Lustre metallic; color dark steel-gray; streak gray, shining.

In a matrass, fuses easily and gives sometimes a little sulphur. In an open tube, fuses to a globule and gives off sulphur dioxide. On charcoal, fuses to a gray metallic globule, which is somewhat malleable; with fluxes the globule gives the reactions of copper, sometimes also those of iron; on a cupel with lead, affords a globule of silver.

Dissolves in nitric acid, leaving a residue of sulphur.

289. Dyscrasite.—Antimonial Silver. Ag_4Sb and other proportions. 78 aq. H. = 3.5–4; G. = 9.4–9.8. Trimetric. Occurs crystalline or massive; granular. Lustre metallic; color and streak silver-white, also tin-white.

On charcoal, fuses readily to a gray, non-ductile globule, and coats the charcoal with antimony trioxide. With continued heat the globule assumes the appearance of pure silver and the coating becomes reddish.

290. Pyrargyrite.—Ruby Silver Ore, $3Ag_2S + Sb_2S_3$. 59.8 Ag. H. = 2–2.5; G. = 5.7–5.9. Hexagonal. Color dark-red to black, giving a cochineal-red powder. Crystallizes in hexagonal prisms. Streak cochineal-red. Lustre metallic-adamantine.

In a matrass, fuses very readily, and yields with continued heat a sublimate of antimony trisulphide. In an open glass tube, gives antimony fumes and sulphur di-

oxide. On charcoal, fuses readily and deposits a coating of antimony trioxide, being converted into silver sulphide; if for a long time exposed to the oxidizing flame, or, when mixed with soda, in the reducing flame, affords a globule of metallic silver.

Part of the Sb_2S_3 is sometimes substituted by As_2S_3; it then gives out arsenic fumes when mixed with soda and heated in the reducing flame on charcoal.

The pulverized mineral, when heated with nitric acid, turns black, and is ultimately dissolved, leaving a residue of sulphur and antimony trioxide. Caustic potash also blackens it and affects partial solution, from which acids precipitate antimony trisulphide.

291. Proustite.—Light-red Silver Ore. $3Ag_2S + As_2S_3$. 65.5 Ag. H. = 2–2.5; G. = 5.4–5.5. Hexagonal. Very much resembles the dark-red silver ore, but is of a somewhat lighter color. Lustre adamantine.

Before the blowpipe and to solvents, behaves like the preceding, excepting it gives off arsenic fumes instead of antimony trioxide. The solution in caustic potash deposits a yellow precipitate when neutralized with acids.

292. Stephanite. — Brittle Silver Ore. $5Ag_2S,Sb_2S_3$. 68.5 Ag. H. = 2–2.5; G. = 6.2. Trimetric. Of metallic lustre and iron-black color and streak; it is very brittle and fragile.

In a matrass, decrepitates, then fuses, and ultimately yields a faint sublimate of antimony trisulphide. On charcoal, fuses very readily, and coats the charcoal with antimony trioxide. If the blast with the oxidizing flame is kept up for a sufficient time, the coating assumes a red color and a globule of metallic silver is obtained. Contains frequently copper and iron, which may be detected by the process described in par. 88. If arsenic is pres-

ent, it gives in the open tube a crystalline sublimate of arsenic trioxide.

In dilute heated nitric acid it dissolves, excepting the sulphur and antimony trioxide; the solution becomes milky on addition of water. Partially dissolved by a boiling solution of caustic potash.

293. Polybasite. $9\,Ag_2S + Sb_2S_3$. 75.5 Ag. H. = 2–3; G. = 6.2. Trimetric. Occurs usually in short tabular prisms or massive. Lustre metallic; color and streak iron-black.

In a matrass, fuses very readily, but gives nothing volatile. In an open tube, gives sulphur dioxide and antimony fumes; the sublimate sometimes contains crystals of arsenic trioxide. On charcoal, gives a coating of antimony trioxide; with continued heat, gives a bright metallic globule, which, on cooling, becomes black on its surface; sometimes a faint coating of zinc oxide is deposited; the metallic globule affords with fluxes the reactions of silver and copper.

With acids, behaves like bournonite.

294. Cerargyrite.—Horn Silver. AgCl. 75.3 Ag. H. = 1–1.5; G. = 5.5. Isometric. Remarkable for its pearl-gray or greenish color, its semi-transparency, resinous lustre, and more especially for its softness, which is so great as to allow it to be marked by the nail. It turns brown on exposure to air. When rubbed with a moistened plate of zinc or iron, the latter becomes covered with a coating of silver. The streak is shining.

It fuses in a candle-flame. On charcoal, is easily reduced, especially when mixed with soda. Mixed with copper oxide and heated on charcoal in the reducing flame, copper chloride is formed, which colors the flame azure-blue (see par. 82).

Insoluble in water and nitric acid. Slowly soluble in ammonium hydrate. Partially decomposed by a boiling solution of caustic potash.

295. Bromyrite.—Silver Bromide. AgBr. 57.4 Ag. H. = 2–3; G. = 5.8–6. Isometric. Occurs usually in small concretions. Lustre splendent; color yellowish-green or green. Sectile.

Before the blowpipe on coal emits bromine vapors and yields a globule of silver. Fused with acid potassium sulphate in a matrass, gives off yellowish-brown vapors of bromine. The globule while hot is intense red, and yellow when cold. Insoluble in nitric acid; difficultly soluble in ammonium hydrate.

296. Embolite.—Chloro-Bromide of Silver. AgBr and AgCl in varying proportions. 61 to 69.8 Ag. H. = 1–1.5; G. = 5.3–5.8. Isometric. Crystallized or massive. Lustre resinous; color various shades of green to dark-yellow.

On charcoal, fuses readily, evolves pungent vapors of bromine, and affords a globule of metallic silver. With soda on charcoal, reduced; on dissolving in water the alkaline mass which has passed into the coal, evaporating the solution to dryness, and treating the residue with acid potassium sulphate as described in par. 79, bromine vapors are given out; the bead while hot is garnet-red, and yellow when cold. Fused with copper oxide on charcoal in the reducing flame, colors the outer flame greenish, then blue (see par. 78).

297. Iodyrite.—Silver Iodide. AgI. 46 Ag H. = 1.5; G. = 5.7. Hexagonal. Soft. Occurs crystallized or in thin plates with a lamellar structure. Color citron-yellow to yellowish-green. Lustre resinous to adamantine.

On charcoal, fuses readily, colors the flame purple-red,

and affords a globule of silver. In a matrass with acid potassium sulphate, gives off iodine vapors, and fuses to a very dark, almost black, globule.

Tocornalite. AgI + HgI. Amorphous. Color pale-yellow.

Minerals containing silver: Native Amalgam, Hessite, Petzite, Sylvanite, Miargyrite, Freieslebenite, Argentiferous Tetrahedrite, Galenite, etc.

ORES OF TIN.

298. Stannite.—Tin Pyrites. (Cu,Fe,Zn,Sn)S. 26 Sn. H. = 4; G. = 4.3–4.5. Probably dimetric and hemihedral. Of steel-gray or iron-black color and metallic lustre. Occurs usually massive, granular, and disseminated. Streak blackish.

In an open glass tube, yields sulphur dioxide and tin oxide, which collect close to the assay-piece, and which cannot be volatilized by heat. On charcoal in reducing flame, fuses to a black scoriaceous globule; in the oxidizing flame, gives out sulphur dioxide and becomes covered with tin oxide. When well calcined by the alternate application of the oxidizing flame and the reducing flame, gives with borax the indications of Fe and Cu. With soda and borax, yields a globule of impure copper.

Decomposed by nitric acid, a blue solution is obtained, and a mixture of sulphur and tin oxide remains undissolved.

299. Cassiterite.—Tin Ore. SnO_2. 78.67 Sn. H. = 6–7; G. = 6.3–7.1. Dimetric. It occurs crystallized in square prisms terminated by more or less complicated pyramids; re-entrant angles are so frequent that they are to a certain extent characteristic; also massive, and in small mammillated masses of fibrous texture, hence

called "wood tin." Color variable, but usually brown or black. The crystals commonly possess a very brilliant lustre.

Infusible in the forceps; the behavior before the blowpipe is that of pure tin oxide (see Table II., 30), excepting that it sometimes imparts to the borax bead a slight yellowish tinge, owing to the presence of iron, and exhibits the reaction for manganese when fused with soda and nitre on platinum-foil.

Insoluble in acids. Fused with caustic potash, yields a mass which is mostly soluble in water.

ORES OF ZINC.

300. Sphalerite.—Blende. ZnS. 67.Zn. H.=3.5–4; G.=3.9–4.2. Isometric. Of very variable color, from yellow to black; of resinous lustre and lamellar aspect, distinctly cleavable. It often occurs crystallized in rhomboidal dodecahedrons. The powder is always light-colored, white or grayish, and dull.

In a matrass, sometimes decrepitates violently, but gives nothing volatile; its color also remains unchanged, excepting the green varieties, which become yellow. Strongly heated in an open glass tube, sulphur dioxide is evolved, and the color of the calcined assay is white, yellowish, or brownish, according to the amount of iron which it contains. Alone, infusible or only rounded at the thinnest edges. On charcoal, decrepitates violently, and in the reducing flame a feeble dark coating of cadmium oxide is usually obtained, which is soon followed by a pure zinc coating, which becomes green when moistened with cobalt solution and heated. With soda on charcoal, is easily reduced, and the characteristic zinc flame may frequently be observed. Iron is readily de-

tected by calcining the mineral in the oxidizing flame and treating the residue with borax.

The pulverized mineral dissolves in nitric acid, leaving a residue of sulphur.

301. Zincite.—Red Zinc Ore. ZnO, containing Mn. 80.26 Zn. H.=4–4.5; G.=5.4–5.5. Hexagonal. Of a deep-red color and high lustre; of distinctly foliated structure and orange-yellow streak.

Infusible alone. Dissolved by borax in the oxidizing flame with manganese reaction. With soda on charcoal deposits a copious coating of zinc oxide.

Soluble in nitric acid without effervescence; in hydrochloric acid with evolution of chlorine.

302. Smithsonite.—Zinc Carbonate. $ZnCO_3$. 52 Zn. H.=5; G.=4–4.5. Hexagonal. Of vitreous lustre, and white, grayish, or brownish color and streak; semi-transparent or opaque. Often stalactitic or mammillary.

Heated in a matrass, loses carbon dioxide, and, if pure, appears after cooling enamel-white. The ZnO is often to a large extent substituted by FeO,MnO,CdO, PbO,MgO,CaO; it then, after cooling, frequently assumes a dark color and gives with fluxes the indications of iron and manganese. Mixed with soda and exposed to the reducing flame, it is decomposed, and zinc oxide deposited on the charcoal, which may be tested with cobalt solution. If the temperature is raised sufficiently high, a zinc flame is sometimes observable. The coating is at first dark-yellow, or reddish when cadmium is present.

It readily dissolves in acid with effervescence; also in caustic potash.

303. Willemite.—Anhydrous Zinc Silicate. Zn_2SiO_4, and often containing a little Mn, Fe, Ca, and Mg. 72.9

Zn. H.=5.5; G.=3.89–4.27. Hexagonal. Lustre vitreo-resinous; weak. Color whitish or greenish-yellow when purest; green to dark-brown when impure. Streak uncolored. Transparent to opaque. Brittle.

Before the blowpipe in the forceps, glows and fuses with difficulty to a white enamel; the varieties from New Jersey fuse from 3.5 to 4. The powdered mineral on coal in the reducing flame, gives a coating, yellow while hot, and white on cooling, which, moistened with cobalt solution and treated in the oxidizing flame, is colored bright-green. With soda the coating is more easily obtained. Decomposed by hydrochloric acid with separation of gelatinous silica.

304. Calamine.—Hydrous Zinc Silicate. $Zn_2SiO_4 + aq.$ 67.5 ZnO, with sometimes a little lead. H.=4.5–5; G. =3.1–3.9. Trimetric. It closely resembles in its physical characters the preceding ore. It becomes electric by heat; the smallest fragment heated attracts light substances.

Infusible in the forceps. In a matrass, yields water and turns milk-white. With borax dissolves it to a transparent glass, which cannot be made opaque by flaming. It dissolves in salt of phosphorus to a transparent glass, which becomes opaque on cooling, and in which, when highly saturated, clouds of silica are observable while hot. With soda on charcoal, swells and affords with difficulty a coating of oxide of zinc. With cobalt solution, assumes a green color, which, when the heat is raised, passes into a fine light blue on the fused edges.

It is readily decomposed by acids, with separation of gelatinous silica. Dissolved by a strong solution of caustic potash.

Minerals containing zinc: Hydrozincite, Aurichalcite, Franklinite.

CARBONACEOUS COMPOUNDS.

305. Graphite.—Plumbago. C, with often a little iron sesquioxide *mixed* with it. Hexagonal. In flat, six-sided tables. H. = 1–2; G. = 2–2.2. Lustre metallic; streak black and shining; color iron-black to dark steel-gray; opaque; sectile; marks paper; thin; laminæ flexible; feel greasy.

It occurs also foliated, columnar, radiated, scaly, granular, and massive.

At a high temperature it burns without flame or smoke, leaving usually some red iron oxide. Before the blowpipe, infusible; fused with nitre in a platinum spoon, deflagrates, converting the reagent into potassium carbonate, which effervesces with acids. Unaffected by acids.

306. Anthracite. C (from 80 to 95 per cent.), with a small percentage of SiO_2, Al_2O_3, and FeO_3. H. = 2–2.5; G. = 1.3–1.8. Lustre bright, often sub-metallic; color iron-black, frequently iridescent; fracture conchoidal.

In a matrass, gives usually a little water, but no empyreumatic oil. Heated on platinum foil in the oxidizing flame, is slowly consumed without flame, leaving a small quantity of ash, which consists of SiO_2, AlO_3, and more or less of FeO_3. Does not color a boiling solution of caustic potash.

307. Bituminous Coal. C,H,O, in variable proportions. The bituminous matter contains from 76 to 90 per cent. of carbon; the earthy impurities consist principally of SiO_2, AlO_3, and CaO; contains frequently a small amount of N and FeS_2. Softer than anthracite. G. = 1.2–1.5. Less highly lustrous than the preceding, and of a more purely black or brownish-black color.

In a matrass, some varieties soften and cake (*caking*

coal), while others are entirely infusible; all varieties are decomposed, evolve combustible gases and empyreumatic oils, and leave a residue of more or less metallic lustre (coke), which behaves like anthracite. On platinum foil, burns with a luminous flame and emission of smoke, leaving an earthy residue.

Boiled with a solution of caustic potash or with ether, imparts to these solvents no color, or only a pale-yellow.

308. Brown Coal. Composition the same as that of bituminous coal, but the organic constituents contain only from 60 to 75 per cent. of carbon. In physical properties bears sometimes a close resemblance to the preceding. Some varieties show distinctly the texture of wood (*lignite*).

In a matrass, infusible, but some varieties soften; evolves combustible gases, empyreumatic oils, water of acid reaction, and a peculiar disagreeable odor, leaving a residue which consists of carbon and a considerable amount of ash. On platinum foil, burns with a smoky flame and emission of a peculiar odor.

Boiled with a solution of caustic potash, colors the liquid brown.

309. Asphaltum. C,H,O, in variable proportions, with about 75 per cent. of carbon. G. = 1–1.8. Of black or brownish-black color and bituminous odor.

Fuses at about 100° C., and burns with a bright flame and emission of a thick smoke, leaving little ash, which consists essentially of SiO_2, AlO_3, and FeO_3. In a matrass, gives empyreumatic oil, some ammoniacal water, combustible gases, and leaves a carbonaceous residue.

Treated with boiling ether, colors the solvent wine-red to brownish-red (distinction from bituminous coal); treated with a boiling solution of caustic potash, does not

color the liquid, or imparts at the most a pale-yellow color (distinction from brown coal).

310. Succinite.—Amber. C,H,O. H.=2–2.5; G.=1.065–1.081. It occurs in irregular masses, without cleavage; lustre resinous; color yellow; sometimes reddish, brownish, and whitish; often clouded; streak white; transparent; translucent; tasteless; electric on friction; fuses at 287° C., but without becoming a flowing liquid.

It consists of succinic acid, resins, an ethereal oil, and succinite proper, an insoluble substance.

Amber fuses with some difficulty in the matrass, yielding water, empyreumatic oil, gases, succinic acid, and a residue of amber resin. It burns with a yellow flame, emitting an agreeable odor, and leaving a black, shining, carbonaceous mass.

311. Elaterite.—Elastic Bitumen. C and H. G.=0.905–1.223. Soft, elastic, like India-rubber, but sometimes hard and brittle. Color dark-brown; subtranslucent. Occurs in compact, reniform, or fungoid masses. Usually with a peculiar suffocating odor.

Burns in the flame of a candle, and gives empyreumatic products when fused in a matrass.

312. Ozocerite. G.=0.85–0.90. In appearance and consistency similar to wax or spermaceti. Color white, yellowish, brown, and leek-green; translucent; feel greasy; wax-like odor; fusibility 56° to 63° C. It has been obtained by destructive distillation from mineral coal, peat, petroleum, etc.

HYDROCARBON COMPOUNDS.

For a partial list of these, see p. 290.

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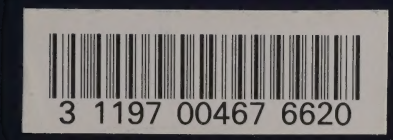
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